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GAS REQUIREMENTS TO PRESSURIZE ABANDONED DEEP MINES. A STUDY OF THE USE OF INERT GASES TO ELIMINATE ACID POLLUTION FROM ABANDONED DEEP MINES

Cyrus Wm. Rice and Company

Prepared for:

Federal Water Pollution Control Administration

September 1969

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GAS REQUIREMENTS TO PRESSURIZE ABANDONED DEEP MINES

A Study of the Use of Inert Gases to Eliminate Acid Pollution from Abandoned Deep Mines

COAL RESEARCH BOARD
COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF MINES AND
MINERAL INDUSTRIES

and

FEDERAL WATER POLLUTION
CONTROL ADMINISTRATION
DEPARTMENT OF THE INTERIOR

by

Cyrus Wm. Rice Division
NUS Corporation
15 Noble Avenue
Pittsburgh, Pa. 15205

Commonwealth of Pennsylvania
Project No. CR-81
FWPCA Project No. WPRD-227

September, 1969

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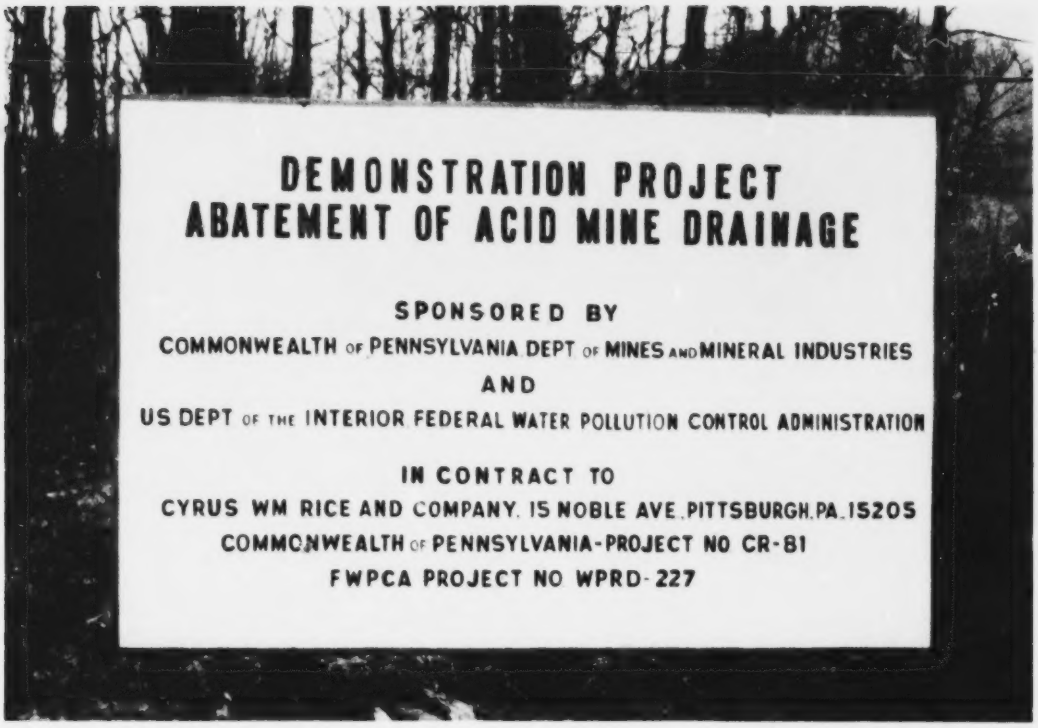
DEMONSTRATION PROJECT
ABATEMENT OF ACID MINE DRAINAGE
SPONSORED BY
COMMONWEALTH OF PENNSYLVANIA DEPT OF MINES AND MINERAL INDUSTRIES
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FWPCA PROJECT NO WPRD-227

FWPCA Review Notice

This report has been reviewed by the Federal Water Pollution Control Administration and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Federal Water Pollution Control Administration.

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1.0 CONCLUSIONS

The purpose of Phase I of the overall project to blanket abandoned deep mines with an inert gas was to determine the gas injection rates needed to develop and maintain slight pressures within a mine over ambient conditions during changes in the barometric pressure. The Whipkey deep mine, having 50 mined acres, was selected for the Phase I study because it was thought to be reasonably "tight;" i.e., having a thick barrier along the outcrop, strong roof with little falling or potholing, and all prior openings well sealed with compacted earth and clay.

From preliminary calculations, it was estimated that gas flows of approximately 650 cfm would be sufficient to develop pressures in excess of 0.25" H_2O in this mine. The equipment purchased for this air-pressurization study had a maximum capacity of 500 cfm, and differential pressures from 0.10" to 0.18" H_2O were obtained from time to time at air flows near maximum capacity. These differential pressures existed from two to six hours, but could not be maintained over extended periods.

After several weeks, attempts to pressurize the mine were stopped when all results indicated the mine was "free-breathing" through one or more unknown openings. Various methods were used to locate the openings or leaks with limited success. In a final attempt, the strip mine was excavated in the area of the original mine openings. It was found that there was less than five feet of cover over these openings and this was concluded to be an area of gas leakage and pressure loss, and thus the reason for the inability to maintain a positive differential pressure within the Whipkey mine during this study.

The study was continued for three weeks at the nearby and smaller (15 acres) King No. 2 mine. Pressurization attempts at this mine were more positive with differential pressure up to 0.28" H_2O being obtained at air flows of 575 cfm. Higher air injection rates were obtained by disconnecting all equipment attached to the motor. In addition, more accurate and steady differential pressures were recorded on an inclined manometer than could be obtained directly from the strip chart recorder. Although the King No. 2 mine is thought to have unlocated openings which permit

air leakage to the atmosphere, steady and increasing differential pressures were obtained during both rising and falling barometric pressures on the final run of the study at an estimated air flow of 575 cfm.

The data obtained during this phase of the study was insufficient to accurately project gas injection requirements to pressurize abandoned deep mines. Although positive pressure differentials were developed, these immediately dissipated when air injection was stopped and this is believed to be due to areas of air leakage to the atmosphere in both of the mines studied. The results of this work indicate that slight pressures can be developed within deep mines at low air injection rates. To determine if these pressures can be developed at lower injection rates, or maintained once gas injection has ceased, it will be necessary to do more extensive sealing of fissures, potholes and porous areas, especially in deep mines of the "drift" or "slope" types. The study should then be continued to develop the data needed to determine optimum injection rates for pressurization, and to characterize air leakage from deep mines.

RECOMMENDATIONS

It is recommended that work in this study be continued to optimize gas injection requirements in both "free-breathing" and "tight" deep mines. This can be accomplished at the two mines currently under study. Although both of these mines are thought to have very few fissures or "potholes," the unsealed openings in the outcrop permit them to be "free-breathing." The location and sealing of these points of air leakage would provide tighter mines for the air pressurization experiments.

It is also recommended that the equipment be modified to increase the air injection rates above the present maximum of 600 cfm. The original air pressurization experiments should be repeated at higher injection rates and the results of both compared to those obtained after the mines are further sealed. From this, the benefits derived in the form of reduced gas injection requirements can be compared to the costs of more extensive sealing.

Once the rate of gas injection required to overcome inhaling of air into a mine during a barometric pressure change is determined, the project can be extended to economically blanket an abandoned mine(s) with an inert gas.

2.0 INTRODUCTION

2.1 General Background

The formation of acid mine drainage is a natural occurring phenomenon that results when pyrites are exposed to air and water. Pyrites, which are minerals containing iron sulfide, generally occur in association with various minerals and ores; such as coal, copper, gold, sulfur, etc. The mining of these minerals and ores, either by surface or subsurface methods, exposes the pyritic materials which subsequently oxidize in the presence of moisture and air to form sulfuric acid and ferrous sulfate. These salts then dissolve in ground or surface waters to form dilute solutions of sulfuric acid and iron sulfate commonly known as "acid mine drainage."

The complete mechanisms of this chemical reaction are not entirely understood, but the overall reaction can be shown as:

$$2FeS_2 + 2H_2O + 7O_2 \longrightarrow 2FeSO_4 + 2H_2SO_4$$

(pyrite) $\longrightarrow$ (ferrous sulfate) + (sulfuric acid)

The ferrous sulfate will oxidize to the ferric form, which then hydrolyzes to form either ferric hydroxide or ferric sulfate, producing a condition in surface streams called "Yellowboy."

The overall result of the oxidation of pyrites is the formation of acid mine drainage, a major source of pollution in the Eastern and Mid-Atlantic States created by coal and other mineral mining. Although the acid water can be neutralized, measures for preventing the formation of acid in subsurface mining operations have not been developed.

The primary technique for abating or preventing the oxidation of pyrites in deep mines is the elimination of oxygen by either flooding the mine with water or to seal its openings, thus preventing the entrance of fresh air. This preventive technique was widely employed by the Works Progress Administration under the direction of the United States Public Health Service during the 1930's. It is estimated that more than 20,000 seals[1] were constructed by this Administration, in order to prevent the discharge of

---

[1] Anon., "Substantial Progress Reported in Mine Seal Program," Coal Mining, 15 (2), 8-10, (1938).

acid mine drainage as well as for other reasons. Although the results of this program are poorly documented in the literature, the information available indicates a substantial reduction in acid pollution. Later work was conducted by S. A. Braley[2] at the Mellon Institute of Industrial Research, Pittsburgh, Pennsylvania, on the prevention of acid formation in deep mines by elimination of oxygen.

Braley's[3] laboratory work further documented this theory when he showed a substantial reduction in the amount of acid formed by controlling the oxygen content in the atmosphere contacting "sulfur ball" pyrite of -8 + 40 mesh in laboratory flasks. He proportioned various mixtures of oxygen and nitrogen and passed these atmospheres through the flasks for two weeks. The amount of acid and sulfate was determined by washing the pyrites with distilled water. His results were as follows:

---

[2] Braley, S. A., "Summary Report of Commonwealth of Pennsylvania (Department of Health) Industrial Fellowship Nos. 1 to 7 Incl.," Mellon Industrial Fellowship No. 326B, (1954), pp. 192-3.

[3] Ibid.

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	100 N_2	99.6 N_2	92 N_2	90.8 N_2	82.9 N_2	Air	0 N_2
Atmosphere Comp.	0. O_2	.4 O_2	8 O_2	9.2 O_2	17.1 O_2	0	100 O_2
Acid ($CaCO_3$ eq.)	31	30	440	476	948	1104	2903
SO_4	34	37	447	494	931	1082	2900

From this work he postulated that there should be no acid formed in an atmosphere consisting of 100% N_2 and any decrease in the oxygen concentration in a mine should decrease the extent of acid formed. Subsequent work in sealing deep mines showed a reduction in acid production as the oxygen level within the mine was reduced by oxidation.

The mine sealing program had limited success in eliminating the acid discharges. The seals generally failed to stop the flow of water; however, many wet seals were successful in preventing air from entering the mine while allowing the drainage to leave. The air retained within the mine, at the time of sealing, was slowly depleted of oxygen by the oxidation reactions and when such was complete, the production of ferrous sulfate and sulfuric acid slowly diminished. The failure of the sealing program in many instances was as much the result of the inability to prevent all air from entering

the mines, as it was of the difficulty of maintaining the effectiveness of the seals. Potholing, fractures in the rock strata above the seam, in addition to the natural fissures present, meant that sealing the main entrances and even filling the potholes could only reduce but never eliminate air from entering the mine.

2.2 Scope of Study

Based on this previous work, it has been recognized that if the atmosphere in abandoned deep mines could be maintained in an inert condition; that is, free from oxygen, the formation of acid by the oxidation process would be stopped and the production of acid mine drainage effectively eliminated. It is surmised that such a condition could be maintained if one could inject a non-oxidizing gas into abandoned mines and maintain this inert condition by creating a slight positive pressure within the mine over the outside ambient conditions. It is known that deep mines "breathe" during barometric changes in the atmosphere. If such a slight pressure could be developed and maintained within the mine, it would then be in a constant state of exhaling, thus preventing the influx of air and oxygen into the mine.

This study is the first phase of a complete inert gas blanketing demonstration project. Phase I involved the pressurization of abandoned deep mines with air to determine the gas injection rates required to maintain positive pressures within the mine during normal barometric changes.

The theorectical calculations for sizing the air blowing equipment are discussed in Section 4.1 and 4.2 of this report. The free-breathing rate of the mine selected for this study was estimated and the equipment used was sized slightly above this rate. The purpose was to select a mine that was reasonably "tight," in order that the air flow would only be through the existing entries and not through unlocated potholes or fissures. For these reasons, the Whipkey deep mine in Ohiopyle State Park, Fayette County, Pennsylvania, was selected as the initial site for the study. Additional work under this study was also conducted at the nearby King No. 2 deep mine. The physical characteristics and history of both of these mines are discussed in Sections 3.1 and 3.2 respectively.

3.0 DEMONSTRATION MINES

3.1 Whipkey Deep Mine

The mine first chosen for this study is known as the Whipkey mine and is located in Stewart Township, Fayette County. The mine was originally opened in 1938 and presently encompasses 150 acres of which 50 acres is estimated to have been mined. The coal seam mined was the Lower Kittanning which has an average thickness of 36 inches in this area. The interval between the Middle Kittanning and Lower Kittanning coal seams is generally characterized as being a massive sandstone and, in this particular case, the sandstone is fine grained with a relatively low porosity. The coal outcrops near the base of a steeply sloping hillside and the overburden above the coal seam rapidly increases to an estimated 275 feet. The coal seam dips to the southeast at a slope of approximately 6% and the strike of the coal is to the northeast. A section of a 7.5 minute U.S.G.S. topographic map showing the area under study appears in Plate 1. A blow-up of this area showing the extent of the Whipkey deep mine appears in Plate 2.

The mine was first opened in the southeast section of the property boundary which is now the lowest point of the mine.

As mining progressed, new entries were driven to the west of the original entries along the southern boundary of the property line. Wherever possible, the coal was mined to the rise to permit gravity drainage from the mine as well as to develop the most advantageous haulage courses. A total of eleven entries were driven into the mine during the period of its inception in 1938 to its closing in 1964.

The southern boundary of the Whipkey mine was strip mined in 1960. The strip mine operator cut into the Whipkey mine in at least five places and, in at least two of these instances, extensively fractured the roof of the deep mine. Plate 3 shows a wide angle photograph of the hillside containing the Whipkey deep mine, and also the strip mined area and the approximate location of the entries. Plates 4 through 11 are photographs of the existing three openings into the upper portion of the Whipkey mine both before and after construction of dry seals.

In 1961 another small mine, known as the Miller mine, was opened directly adjacent to the southeast section of the Whipkey mine. The mine was never developed to any great

extent; however, at one time the operator cut deeply into a barrier pillar between a flooded portion of the Whipkey mine, and, as a result, temporarily flooded the Miller mine.

In 1964, the Western Pennsylvania Conservancy purchased the coal and surface rights of the Whipkey mine. Although the Conservancy was able to purchase the coal rights of the Miller mine, they have been unable to obtain the surface property to date. The Conservancy then funded money for the backfilling and revegetation of the strip mined area; however, this could be accomplished only as far as the Miller mine since the surface area was still privately owned. At the present time the strip mined area is backfilled to a depth of approximately four feet above the Whipkey deep mine. At the time the strip mine was being backfilled, a wooden flume was installed at the original Whipkey mine entry to prevent water from accumulating in the deep mine. The previous release of a large slug of acid water, through the Miller mine created serious problems in downstream public water plants. This wooden flume still exists and has an average flow of 40 gpm in the summer months and approximately 3 gpm throughout the winter. A photograph of this discharge appears on Plate 13.

The discharge from the Whipkey mine enters a tributary of Cucumber Run. Below the confluence of these two streams is Cucumber Falls, a scenic point of interest in the Ohiopyle State Park. In the early 1960's, Cucumber Run became grossly polluted with acid mine drainage. Approximately 80% of the present pollutional load of Cucumber Run is estimated to originate from the Whipkey deep mine.

3.2 King No. 2 Mine

The King No. 2 mine was opened in 1959 and encompassed approximately 56 acres of which 15 acres is presently thought to have been mined. The coal seam was the Lower Kittanning, which, as previously described, has an average thickness of 36 inches in this area. The coal outcrops near the base of a steeply sloping hillside and the overburden above this mine varies up to approximately 170 feet. A blow-up of the 7.5 minute U.S.G.S. topographic map of this area appears in Plate 12 and shows the location, extent of mining and entries of the King No. 2 mine.

The mine was first opened in the northeast section of the property which is now the point of drainage from the mine.

As the mine developed, three additional entries were driven to the southwest of the original entries in order to shorten the haulage route. Mining was developed to the rise to permit gravity drainage from the mine and for ease of coal removal. Plates 14 and 15 are photographs of the middle entry which was used as the point for air injection during this study.

In 1961, a strip mine operator began to remove overburden from the coal seam along the northwest border of the mine. Although this operator did not strip any coal, he did cut into a haulage tunnel at the northwest edge of the deep mine. This section of the haulage tunnel was then filled and the strip mine was not further developed. A typical view of the overburden above the mine appears in Plate 16 which is a photograph of the strip mine highwall approximately 300 feet southwest of the portal used for air injection.

In 1964, the Western Pennsylvania Conservancy purchased the coal and surface rights of the King No. 2 mine. The Conservancy then funded money for the sealing of the deep

mine with concrete block seals. Two wet seals were installed in the lower entries and solid seals were installed in the three upper entries. All seals are still intact and the two wet seals have a combined average flow of 25 gpm in the summer months and approximately 2 gpm throughout the winter. This discharge enters Cucumber Run approximately one mile above Cucumber Falls.

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FORT NECESSITY QUADRANGLE
PENNSYLVANIA–FAYETTE CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
SE/4 UNIONTOWN 15' QUADRANGLE

5163 IV (CONFLUENCE) 1 62 50'

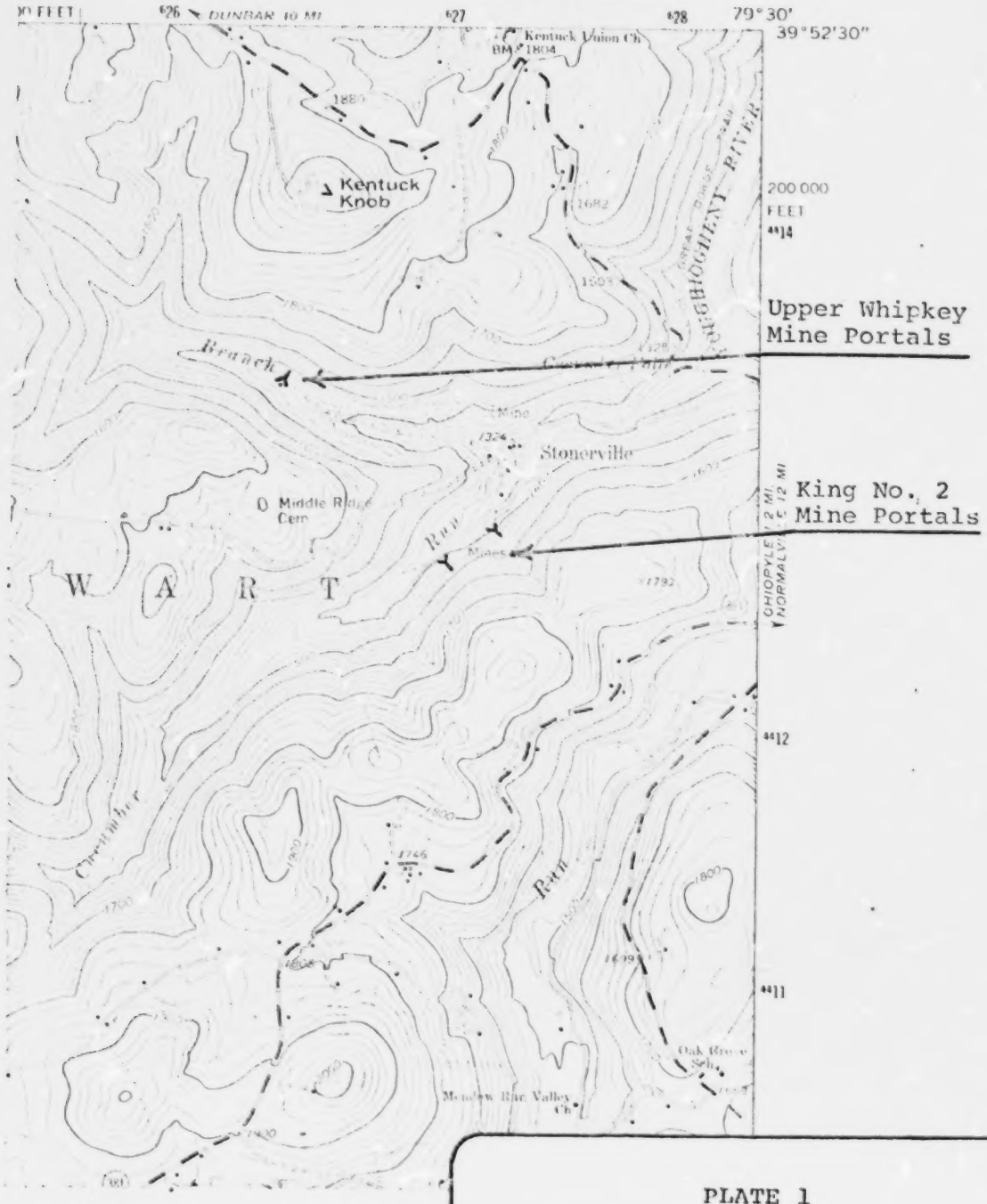
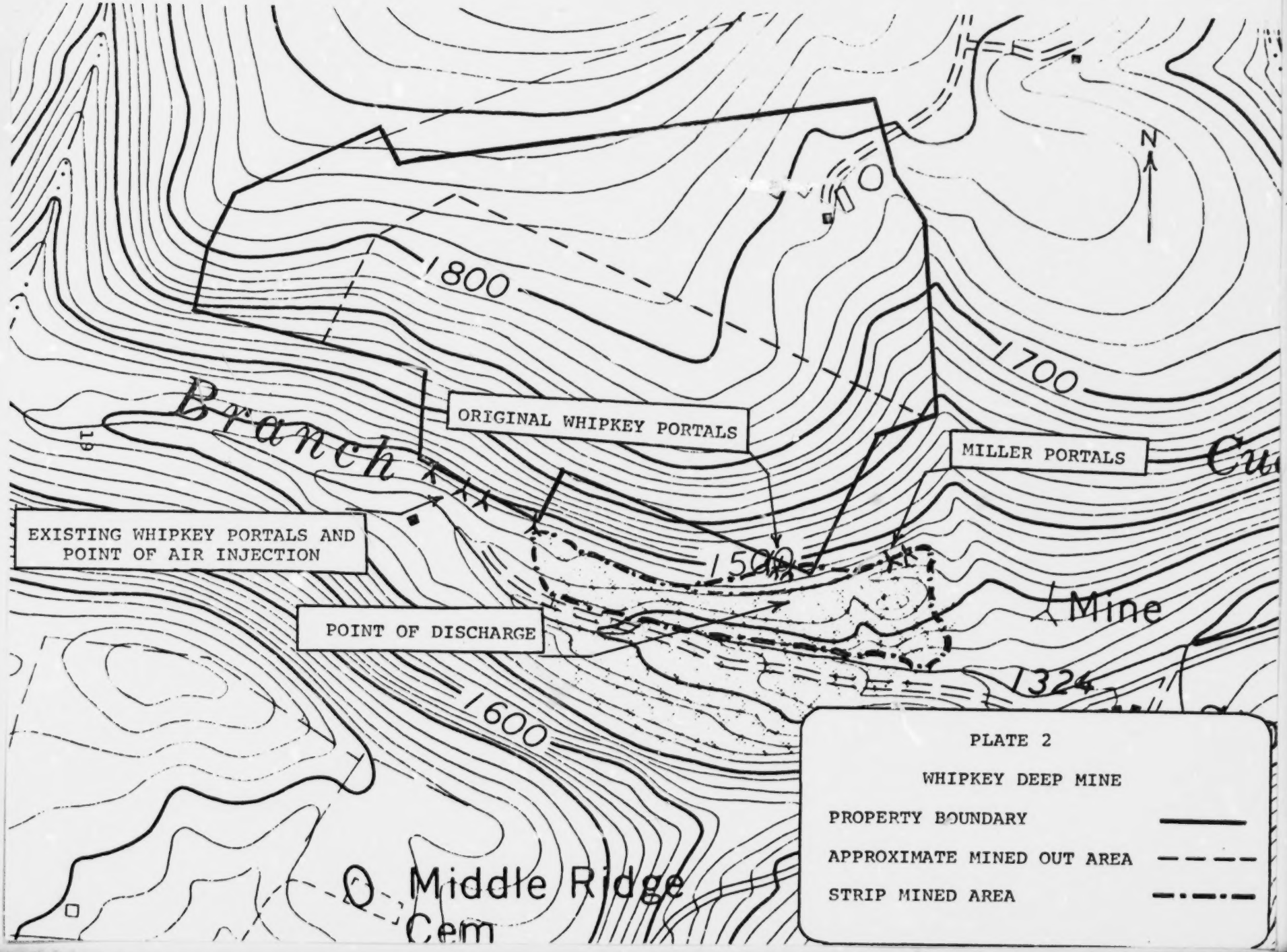


PLATE 1

U. S. G. S.
7.5 MINUTE SERIES (TOPOGRAPHIC)
FORT NECESSITY QUANDRANGLE

"CUCUMBER RUN WATERSHED"


N
1800
1700
1500
1600
Branch
ORIGINAL WHIPKEY PORTALS
MILLER PORTALS
EXISTING WHIPKEY PORTALS AND POINT OF AIR INJECTION
POINT OF DISCHARGE
Mine
1324
Middle Ridge
Cem
PLATE 2
WHIPKEY DEEP MINE
PROPERTY BOUNDARY
APPROXIMATE MINED OUT AREA
STRIP MINED AREA

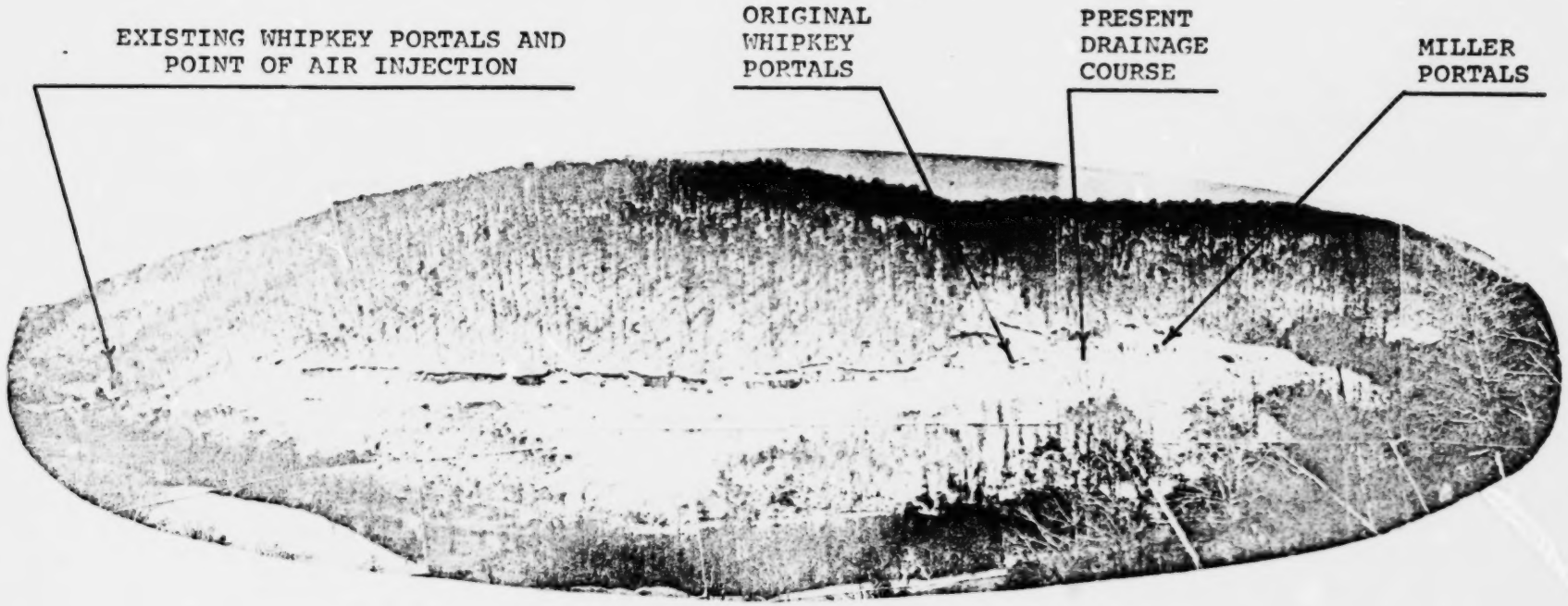


PLATE 3
LITTLE CUCUMBER RUN VALLEY
SHOWING WHIPKEY DEEP MINE AND
ADJACENT STRIP AREA - JANUARY, 1968

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best available copy.

PLATE 4

MAIN AND LOWER PORTALS OF WHIPKEY MINE BEFORE START OF PROJECT AND SEALING
MAY, 1968

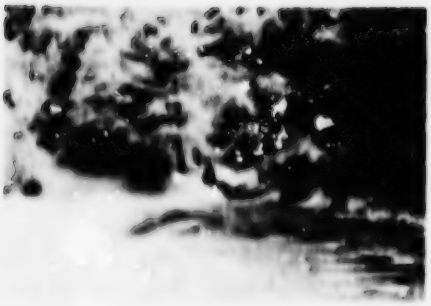


PLATE 5

MAIN PORTAL OF WHIPKEY MINE BEFORE SEALING
MAY, 1968

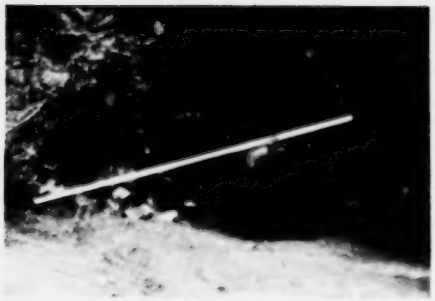


PLATE 6

LOWER PORTAL OF WHIPKEY MINE AFTER REOPENING AND SEALING
AUGUST, 1968

PLATE 7

MAIN PORTAL OF WHIPKEY MINE AFTER REOPENING AND SEALING
AUGUST, 1968

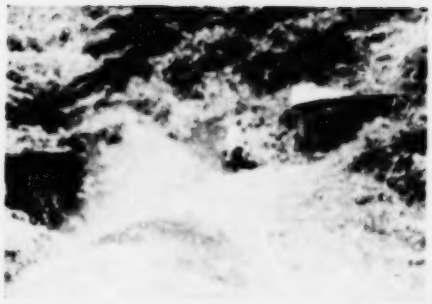


PLATE 8

AIR SHAFT AT WHIPKEY
MINE BEFORE SEALING
MAY, 1968

PLATE 9

AIR SHAFT AT WHIPKEY
MINE AFTER SEALING
MAY, 1968

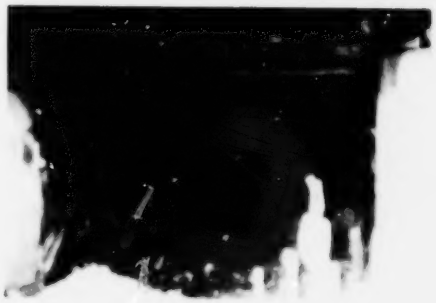


PLATE 10

VIEW INSIDE WHIPKEY MINE
AIR SHAFT PRIOR TO SEALING
JANUARY, 1968

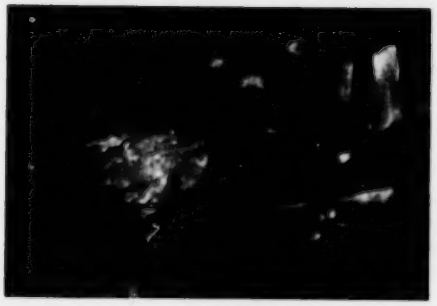


PLATE 11

VIEW INSIDE WHIPKEY MINE
AIR SHAFT BEFORE SEALING
SHOWING REFUSE BUT LITTLE
ROOF FRACTURING
JANUARY, 1968

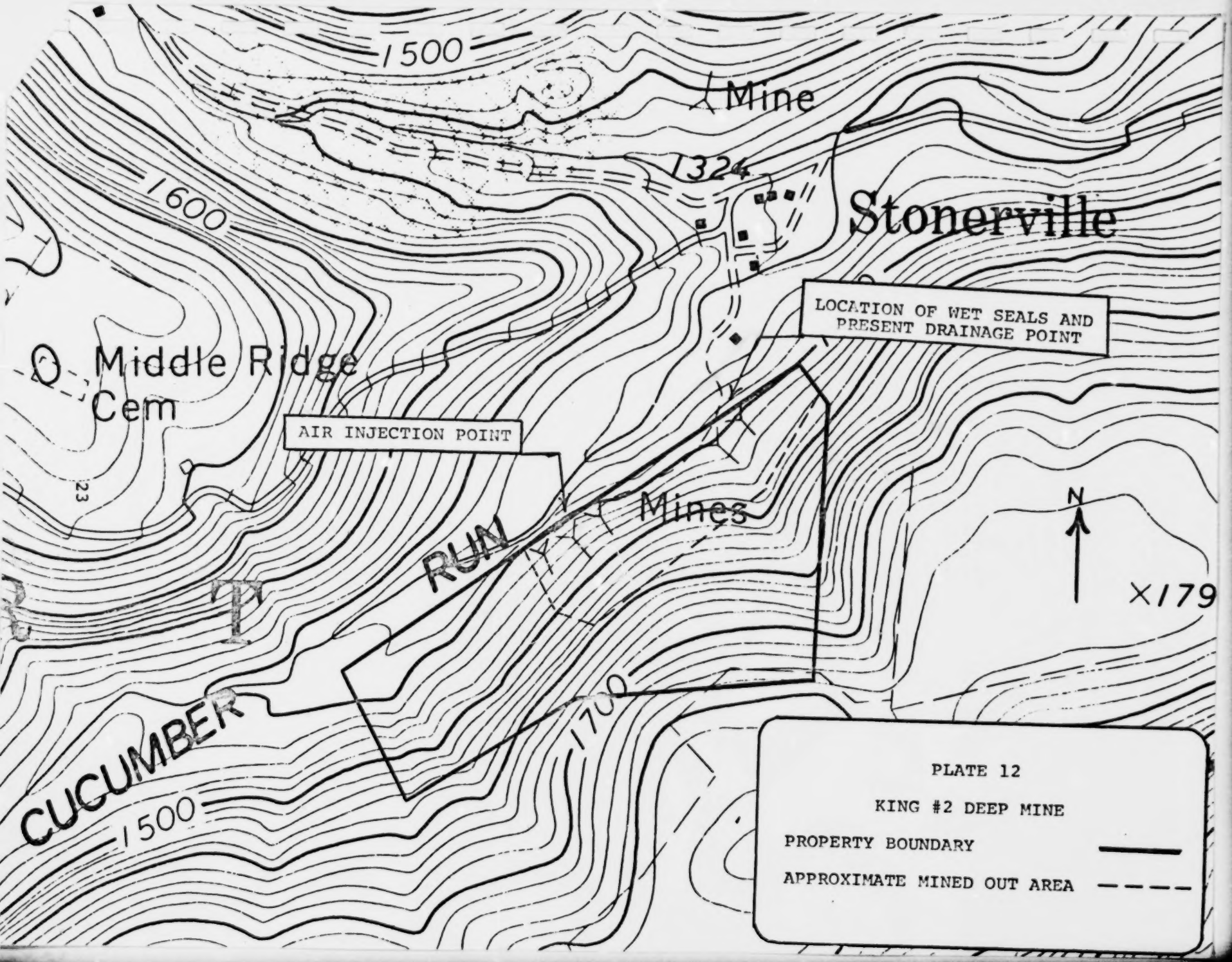

1500
Mine
1324
1600
Stonerville
LOCATION OF WET SEALS AND PRESENT DRAINAGE POINT
Middle Ridge Cem
AIR INJECTION POINT
Mines
RUN
N
X179
CUCUMBER
1700
1500
PLATE 12
KING #2 DEEP MINE
PROPERTY BOUNDARY
APPROXIMATE MINED OUT AREA

PLATE 13

DRAINAGE FROM LOWER
PORTION OF WHIPKEY MINE
MAY, 1968

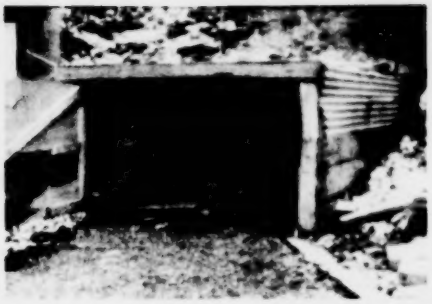


PLATE 14

MAIN PORTAL OF KING NO. 2
MINE SHOWING ENGINE AND
BLOWER ASSEMBLY
DECEMBER, 1968

PLATE 15

TRAILER SHOWN AT RIGHT
OF KING NO. 2 MINE PORTAL
WITH STRIP MINE
BACKGROUND
DECEMBER, 1968

PLATE 16

TYPICAL OVERBURDEN ABOVE
KING NO. 2 MINE
DECEMBER, 1968

4.0 SYSTEM PARAMETERS AND ENGINEERING CALCULATIONS

The Whipkey deep mine was originally selected as the site for the first phase of the overall project. The purpose of this phase was to determine the volume of a gas that must be pumped into a mine to maintain a slight positive pressure over barometric conditions at all times. Such a pressure would insure against a mine "inhaling" which occurs when the barometric pressure is rising, or is at a "high."

Based upon preliminary calculations, it was decided to construct dry seals in the upper openings to the mine and inject air with a positive-displacement blower driven by an air-cooled, gasoline engine. Air flow into the mine from the blower was measured by a laminar flow metering system; ambient pressure with a very sensitive and accurate barometer; mine pressure by an electronic differential pressure system; ambient and mine temperature were also measured. The entire system was operated on 110 volt A.C. current generated by a 12 volt alternator attached to the gasoline engine. All measurements were recorded on strip chart recorders. The

entire system was designed to be as mobile as possible and therefore, as much of the instrumentation as possible was mounted in a trailer.

In order to determine the range of air blowing rates to be used during this study, both the free-breathing rate of the mine and the air flow required to create a slight differential pressure were calculated.

4.1 Free-Breathing Rate

Coal was known to have been removed from the Whipkey mine to the extent of approximately 50 acres. The mine had a working height of 42 inches and the estimated coal removal was 60%. The abandoned mine, if completely open, with little roof collapse, would have a void volume of:

$$50 \text{ acres} \times 43{,}560 \text{ ft}^2/\text{acre} \times 3.5 \text{ ft} \times 60\% = 4.57 \times 10^6 \text{ cu.ft.}$$

To determine the free-breathing rate, it is known that there are typical barometric high's and low's of 30.50" Hg and 29.85" Hg, respectively in western Pennsylvania. During adverse conditions, a complete change from a high to a low

might occur within a 48 hour period. A maximum rate of change could be as much as 0.2" Hg in a 3 hour period. Using this information, the maximum free-breathing rate was calculated for the unsealed Whipkey mine by Boyle's Law:

$$P_1V_1 = P_2V_2$$
$$V_2 = P_1V_1/P_2$$
$$= 4.57 \times 10^6 \ (29.85/30.05)$$
$$= 5.54 \times 10^6 \text{ cubic feet}$$

A volume change of 32,000 cubic feet of air could be expected to enter or leave the mine (depending upon rising or falling barometric pressure) under the adverse conditions of a 0.2" Hg change over a three (3) hour period. To overcome this free-breathing, a minimum air injection rate of 180 cfm would be required.

4.2 Mine Pressure Requirements

In order to develop a slight pressure within the mine, all sizeable openings and fissures would have to be sealed and air injected at a rate that would overcome any air flow into the mine from the atmosphere, especially during periods

of rising barometric pressure. The air flow rate (Q) required to develop a slight, but positive pressure of 0.25" H_2O was estimated by the equation:

$$P_a - P_b = (G^2/g_c \bar{\rho}) (2fL_e/D_e)$$

where

P_a = final pressure = 29.85" Hg = 405.84" H_2O = 2111.29 lb-force/ft^2

P_b = inlet pressure required = 405.84" + 0.25" = 406.09" H_2O = 2112.48 lb-force/ft^2

G^2 = $(w/s)^2$

w = mass flow rate, lb/sec

s = cross-sectional area = 10' x 3.5' = 35 ft^2

g_c = gravitational constant = 32.174 ft-lb/lb-force-sec^2

L_e = equivalent length = 4.57 x 10^6 cu.ft/35 ft^2 = 130,700 ft.

D_e = equivalent diameter = 5.19 ft. from hydraulic radius

$\bar{\rho}$ = average density of air = 0.0808 lb/ft^3 @ 70°

f = friction factor, assumed = 0.1 minimum

In using this equation to determine the mass flow rate w, the following assumptions were made:

a. The volume of the mine was converted to one continuous passageway; 130,700' x 10' x 3.5' high.

b. The air flow through the passageway is adiabatic.

c. A residual pressure of 0.25" H_2O must be added to the barometric pressure to determine the required inlet pressure.

$$w = \left[\frac{(p_a - p_h)\ g_c\ D_e S^2}{2\ f\ L_e}\right]^{1/2}$$

$$= 0.867 \text{ lb/sec}$$

$$Q = 0.867 \text{ lb/sec} = 650 \text{ cu.ft/min.}$$

These calculations indicated that a gas injected at the rate of 650 cfm should be sufficient to create a slight positive pressure of approximately 0.25" H_2O.

5.0 FIELD DEMONSTRATION EQUIPMENT

After selection of the field site for the demonstration project was completed, the acquisition of the field equipment began. It was decided to mount all recording and monitoring equipment in a trailer and a 16 foot model was selected. The trailer was outfitted with living equipment (cot, and gas operated heater, stove and refrigerator) in order that the field personnel could remain at the site for 24 hour periods or longer. A schematic showing the trailer equipment arrangement appears in Figure 1, and photographs of the trailer and its inside in Plates 19 and 17 respectively.

The power supply to operate the electrical transmitting monitors originated from a 12 volt alternator on the gasoline engine used to drive the blower. This D.C. current was converted to 110 volt A.C. by an invertor. In addition, a 16 hour emergency power supply was maintained by use of eight 12-volt storage batteries.

This demonstration project functioned around the use of a 3 lobe, rotary, positive displacement blower manufactured by the M-D Division of MGD Pneumatics, Inc. The blower was a light duty unit, Model 11-5509 capable of producing a maximum pressure of 10 psi at 3600 rpm.

The blower was driven by an Onan Model CCK industrial engine. This gasoline engine is a two cylinder, two cycle unit capable of producing 12.9 horsepower at 2700 rpm. The engine was coupled to the blower by a 5-1/2" diameter direct mounted Rockford clutch. A photograph of the engine-blower assembly is shown in Plate 20 and arrangements of the equipment at both the Whipkey and King No. 2 mines in Figures 2 and 3 respectively.

The air flow rate from the blower into the mine was measured by a laminar flow metering system manufactured by the Meriam Instrument Company, Model 50MC2-4P. This system was capable of measuring 400 cfm at 8" H_2O. The unit converted turbulent air flow to laminar flow and measured differential pressure on a Meriam Model 40HE35 WM Inclined Tube Manometer which has a 50" scale length with graduations of 0.01". Also provided was a Meriam Model 30EB25 WM well type manometer. This unit

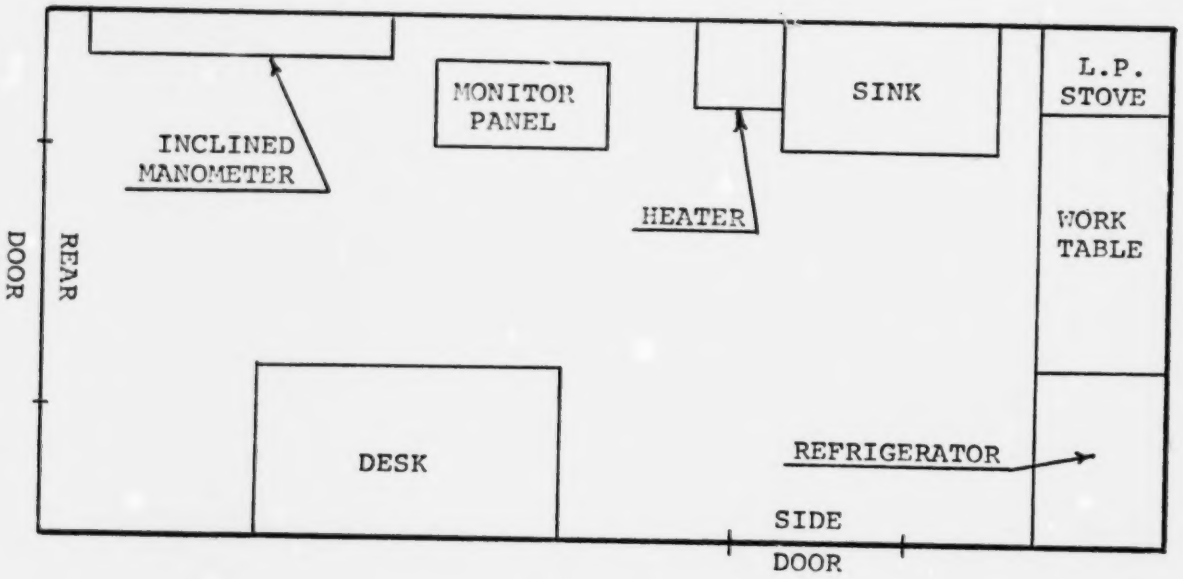
measured the upstream air flow pressure including mine pressure, line pressure drop, and flow cell differential pressure to indicate the density of the gas. This, in turn, was used to determine the volume of gas being injected into the mine. This manometer has a 20" scale length with graduations of 0.1".

The differential pressures were recorded on a Model 6400H automatic recorder manufactured by the Foxboro Company. Two such recorders were used for this study, one having two pens and the other three, in order to provide a continuous record of ambient and mine temperatures, differential mine and gas flow pressures, and ambient humidity. Pressure differentials were transmitted to the automatic recorders by two Fischer & Porter Co. Model 10B2494AA Electronic Differential Pressure Transmitters which operated in a range of 0" - 2" or 0" - 20" water pressure. The principle of operation of this instrument is the difference between two pressures as sensed by a measuring diaphram which converts the differential pressure into an output current. A typical installation of the temperature and differential pressure cells through the mine seals is shown in Figure 4.

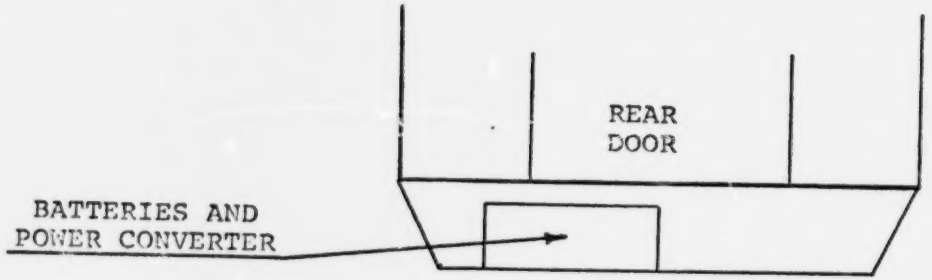
The differential pressure cell was coupled in parallel with a Model 66 K Integrator and Model N 129YK Kessler-Ellis Six Digit Manual Reset Totalizing Impulse Counter. The integrator converts the output current from the D/p cell to a pulse rate output which is used to actuate the electromechanical counter. The counter can be used for a very accurate account of the total gas volume pumped into the mine over an extended period. A schematic of the instrumentation system is shown in Figure 5 and a photograph of this instrument panel on Plate 18.

An Electric Controller, Model 854, was purchased from the Hays Corporation to precisely regulate the volume of air pumped into the mine; however, it was later discovered that the engine throttle afforded sufficient regulation and the controller was not used.

Barometric changes were recorded on a Taylor Cyclo-Stormograph. This barometer has a range of 3.0" Hg with graduations of 0.1" which are readable to 0.01".



FLOOR PLAN



REAR VIEW

FIGURE 1
LAYOUT OF EQUIPMENT
MOUNTED IN TRAILER

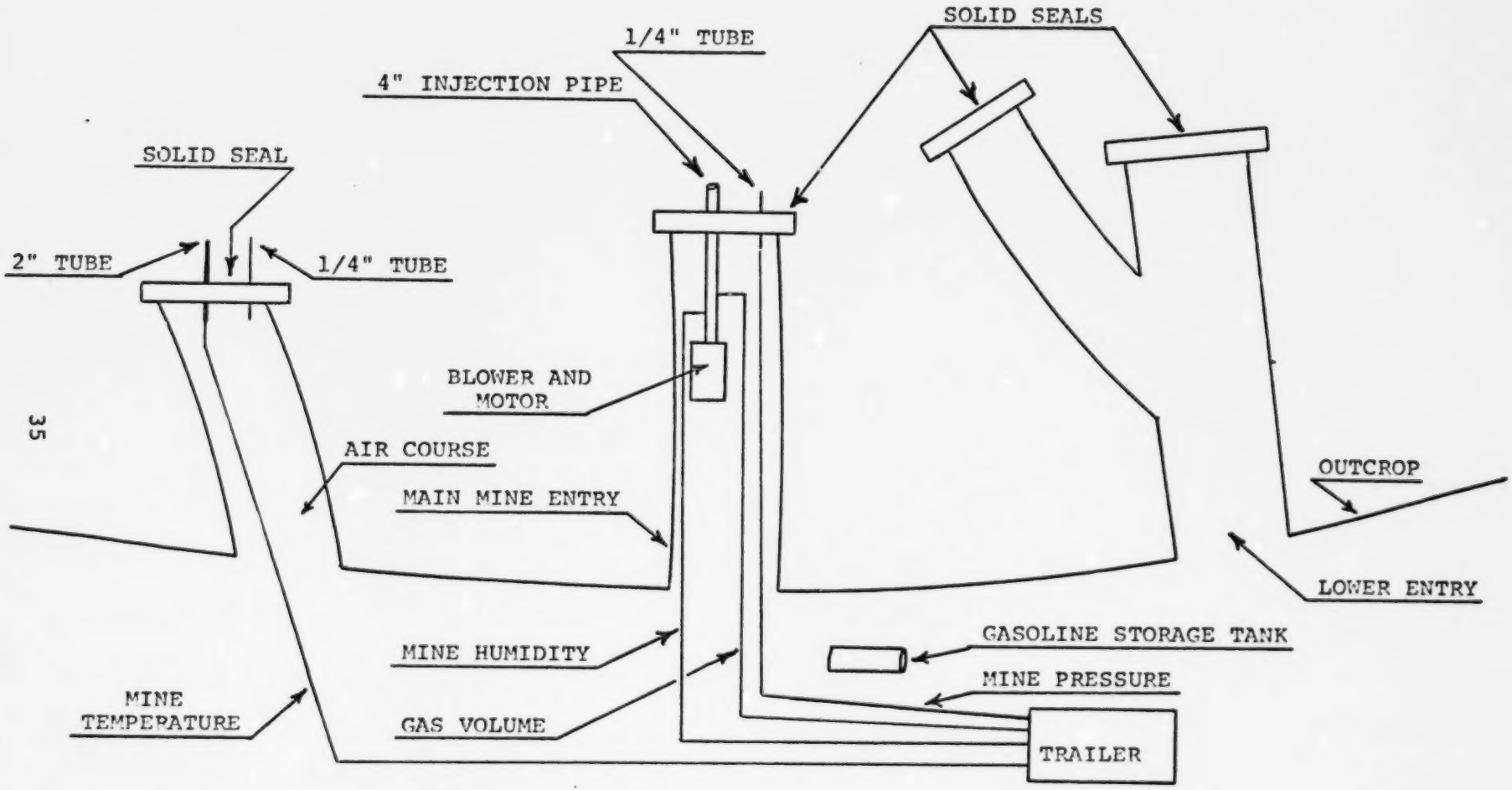


FIGURE 2
SCHEMATIC CONFIGURATION OF EQUIPMENT
AT WHIPKEY DEEP MINE

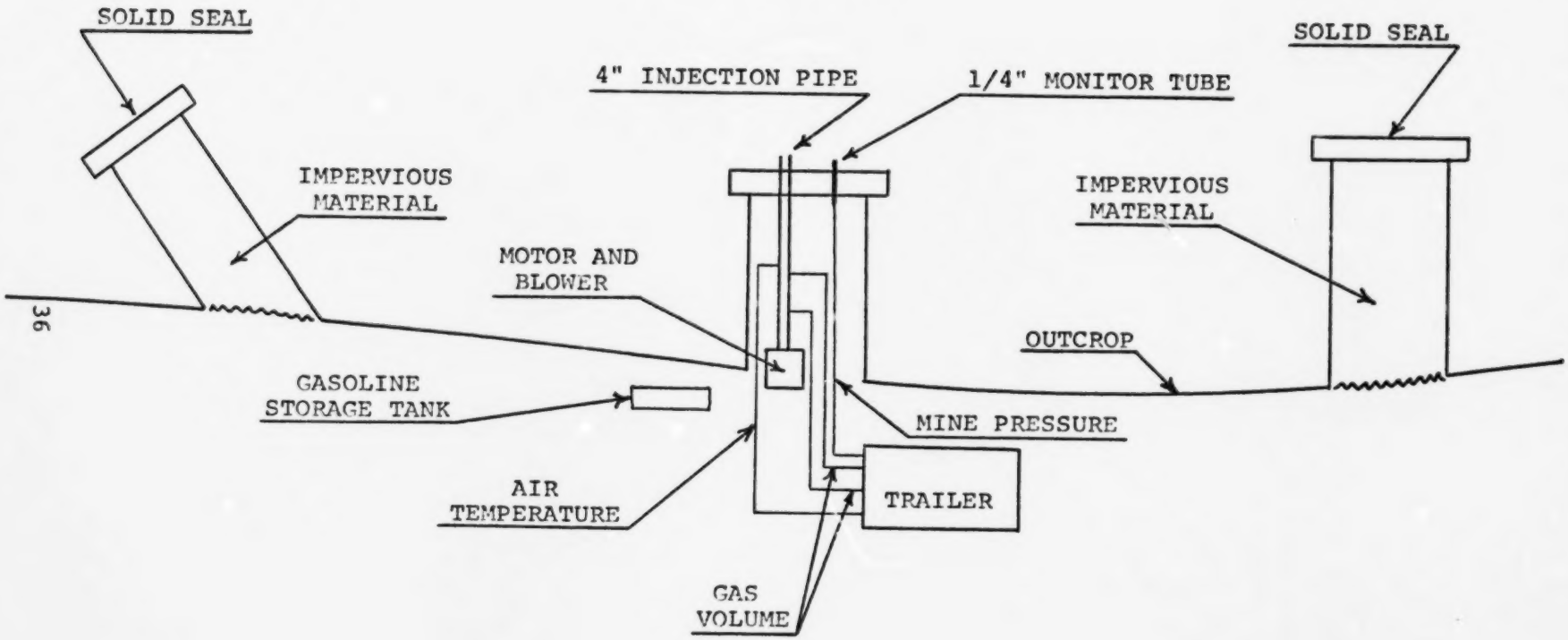


FIGURE 3
SCHEMATIC CONFIGURATION OF EQUIPMENT
AT KING NO. 2 MINE

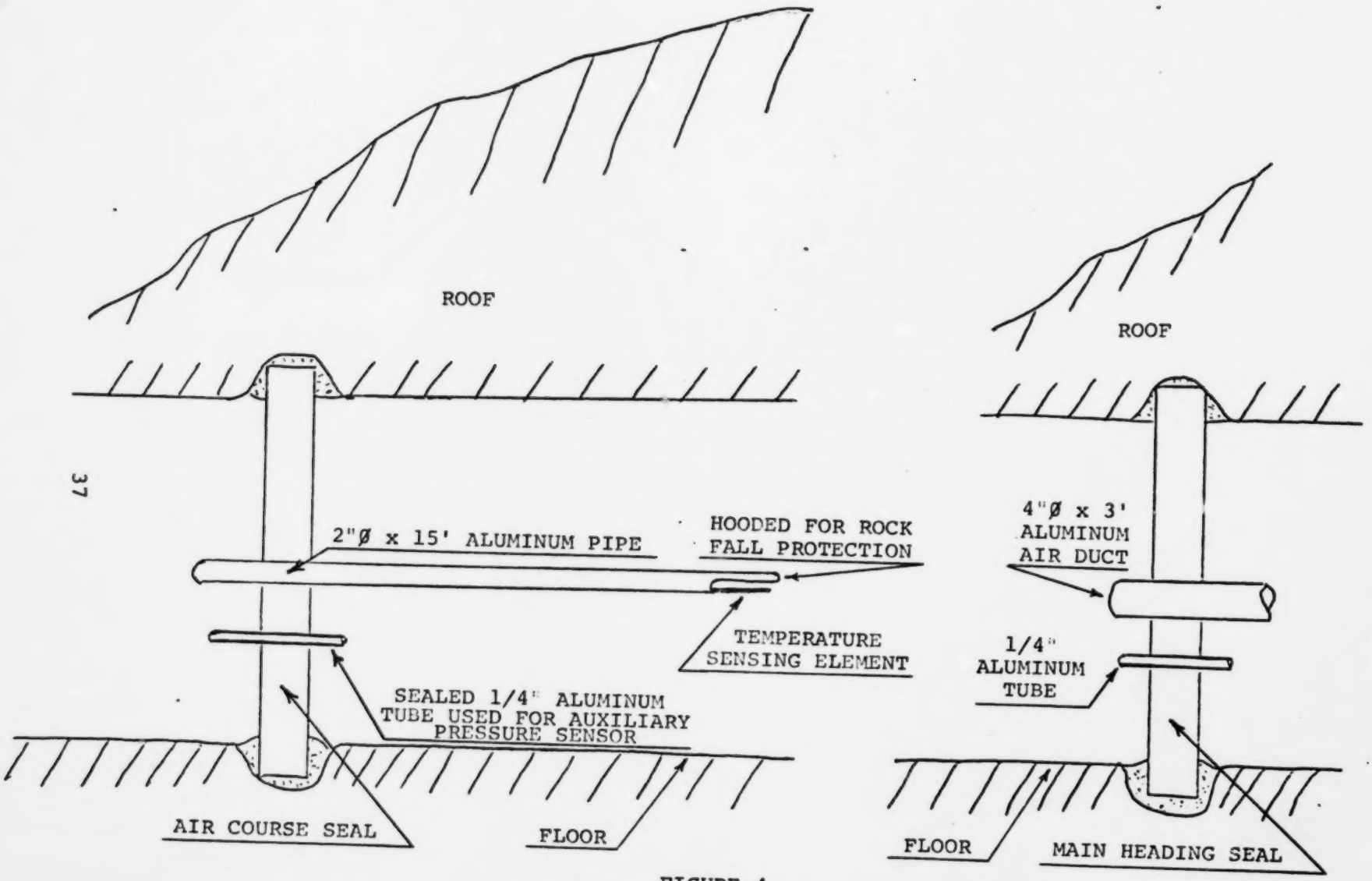


FIGURE 4
TYPICAL INSTALLATION OF MONITOR
CELLS THROUGH MINE SEALS (WHIPKEY MINE)

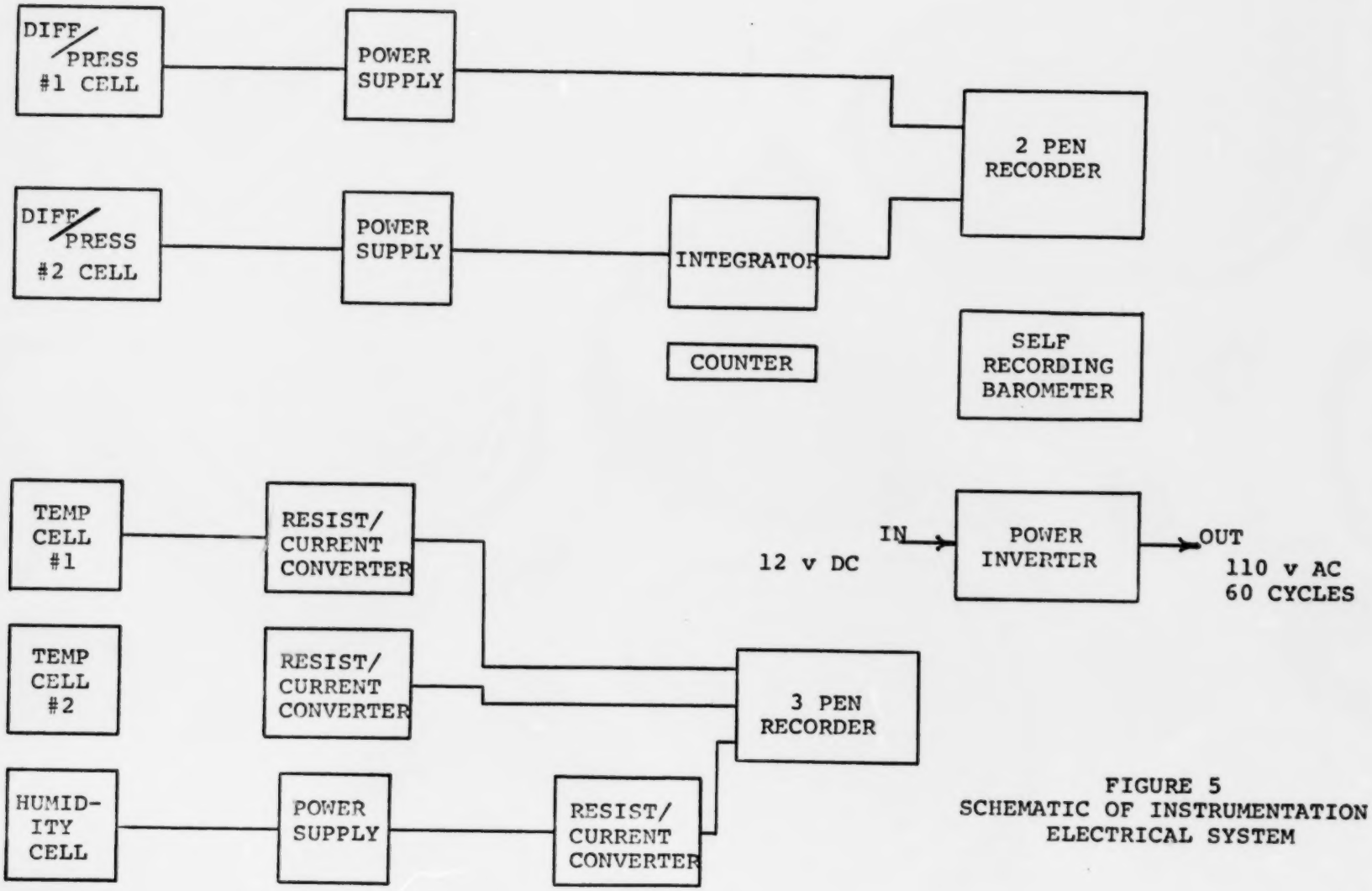


FIGURE 5
SCHEMATIC OF INSTRUMENTATION
ELECTRICAL SYSTEM

PLATE 17

INSIDE OF TRAILER SHOWING
INSTRUMENT PANEL IN
FOREGROUND
AUGUST, 1968

PLATE 18

INSTRUMENT PANEL CONTAINING
DIFFERENTIAL PRESSURE
INDICATING RECORDING
EQUIPMENT. INCLINED
MANOMETER IN BACKGROUND
AUGUST, 1968

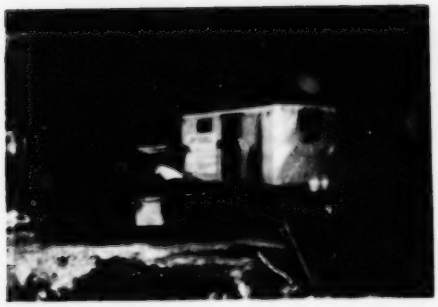


PLATE 19

TRAILER SHOWN NEAR
WHIPKEY MINE OPENINGS
MAIN PORTAL AT LEFT
AUGUST, 1968

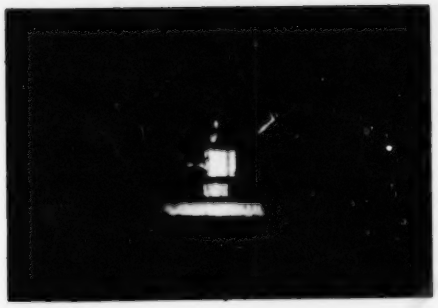


PLATE 20

ENGINE AND BLOWER ASSEMBLY
INSIDE MAIN PORTAL.
CONCRETE SEAL IS 10 FEET
IN BACKGROUND
AUGUST, 1968

6.0 PROJECT OPERATION

6.1 Whipkey Mine

On August 22, 1968, the final calibration of all instruments essential to the initial start-up of the project was completed. During the field calibration, it was found that the Dewcel and also the integrator-counter which records the volume of air blown into the mine, were faulty and these were returned for replacement or repair. The motor and air pumping equipment were started and initial air flow was set at 375 cfm.

After one week of continuous pumping, it was apparent that a differential pressure was not building-up within the mine. It was then found that the mine pressure recording instrument which had been set to measure pressure in inches of water, was calibrated for too wide a range. This unit was recalibrated to record pressure in hundredths of an inch of water. In addition to this, an inclined manometer was fabricated to very accurately measure mine pressure as both a standby unit and a method of determining proper calibration.

The operation of the air pumping equipment was interrupted for approximately one week due to difficulties in engaging the clutch. The clutch supplied by the manufacturer was a grease lubricated model and it was found that one of the lubrication fittings had leaked grease into the housing. This, consequently, led to slippage of the clutch and finally resulted in scorching of the clutch face. Replacement parts for the clutch were ordered and the clutch was repaired as soon as possible.

In the interim, mine pressure versus atmospheric pressure was closely observed on the fabricated inclined manometer. After several barometric pressure cycles, it was evident that a very slight differential pressure was exerted during atmospheric pressure drops. Although the mine seals were apparently affording some restraint during periods of mine exhaling, the mine was still basically open and free-breathing.

With the aid of a former operator of the mine, a large opening into the mine was located on September 6, 1968. This was at one time an air course for the mine and when the strip

mine was backfilled the air course was covered over by several feet of rocky soil. It had since eroded and caved in to the point that tunnel supports were visible. Flow measurements were taken at this old air course while pumping air into the mine. It was determined that the amount of air being expelled from this opening corresponded very closely to the amount of air being pumped into the mine. The tunnel was reopened, all debris removed, and then resealed on September 10th, with approximately 10 feet of impervious material.

Approximately one hour after construction of the seal had been completed, it was noted that a slight positive differential pressure was being recorded for the first time. Air flow into the mine at that time was approximately 420 cfm. This pumping rate was maintained for approximately one week. The results obtained appear in Table 1 and are plotted in Figure 6 in the Appendix. Although a trend did not establish at that time, differential mine pressure seemed to increase as atmospheric pressure decreased and vice versa. Mine pressure dropped to zero at the slightest barometric pressure increase. This problem pointed to the

presence of either unlocated openings in the mine of significant size or many small openings of smaller dimension. It was obvious that these openings must be located and sealed, in order to build-up the differential pressures needed to calculate the air blowing requirements for injection of inert gases into mines of various sizes.

The first attempt to locate the leaks was merely to operate the blower at a flow rate of 500 cfm while the entire strip area was walked. There were no obvious areas where drafts or gas outflow was observed. At this point, it was suggested to make chemical smoke by injecting titanium tetrachloride into the mine through the air blower facilities. Approximately eight 1-pint bottles of titanium chloride was added to the mine over a period of about one hour on September 20, 1968. It was hoped that the titanium chloride would hydrolyze to titanium dioxide smoke. During and immediately after this chemical was added, the only obvious areas where smoke could be seen exiting from the mine were weepages near the mine seals. It was judged that these weepages were insufficient to account for the inability of the mine to hold air.

It was thought that better results would be achieved, if a large quantity of titanium tetrachloride were added over a longer period of time to thoroughly blanket the mine with smoke. Accordingly, on October 4, five gallons of titanium tetrachloride liquid was added to the mine with the blower running. This had approximately the same results as with the previous 8-pint batch. Subsequently, it was decided to vaporize, or distill titanium tetrachloride into the mine with the blower running, hoping to disperse this chemical throughout the mine and have it convert in the mine to titanium dioxide smoke. This was to be done during a period when the climatic conditions were relatively dry with clear weather, and when the barometer was either ascending to a high or just after descending from a high.

Prior to distilling the titanium tetrachloride into the mine, two pints of oil of Wintergreen were pumped into the mine via the blower, with hopes that odors would aid in the location of any mine leaks. Other odor producing chemicals were considered such as chloropicrin, a strong lachrymator, or mercaptans which have been used to detect leaks in gas pipeline systems. It was concluded that the use of such indicators

could have noxious or objectionable consequences to the surrounding area, especially if such indicators were to dissolve in the water exiting from the mine. It was, therefore, decided to use a more pleasant smelling scent such as oil of Wintergreen. The oil of Wintergreen was pumped into the mine over a 24-hour period and the overlying area was then extensively searched. Although a slight odor was believed to have been detected along the strip area, it could not be pinpointed nor was it detectable at the same point later in the day. In the mine air course, where small leaks had been discovered by titanium dioxide smoke, there was a definite odor of oil of Wintergreen; however, this odor was so weak that it is doubtful that it could be recognized in an open, windy environment.

Two subsequent attempts to locate the mine leaks by the vaporization of titanium tetrachloride were unsuccessful. It is believed that, in the extensive and convoluted passageways of the mine, the titanium dioxide smoke could have condensed on the moist tunnel walls before it could be adequately dispersed throughout the mine. It is also possible that the volume of smoke produced from this vaporization was insufficient to

totally blanket the mine to the concentration required in order to see this smoke being emitted. Also, the porosity of the strip area backfill material is too great to permit any substantial buildup of pressure in the mine and the indicating smoke is insignificant over this very large area. It is also conceivable that room collapse could have occurred in the mine, thus preventing the chemical smoke from escaping to the atmosphere.

A final attempt was made to develop a differential pressure within the Whipkey mine during the period November 1 to 5, 1968. Air was blown into the mine at a constant rate of 500 cfm and small differential pressures were developed only during a "fall" in the barometric pressure. This differential was not maintained, but would dissipate within a few hours during steady ambient pressure indicating that the mine was free-breathing. The data obtained is tabulated in Table 3 and is plotted in Figure 8, in the Appendix.

Because of the negative results obtained during the week of November 1, 1968, a joint meeting was held with representatives of the Pennsylvania Coal Research Board, Federal Water

Pollution Control Administration, and Cyrus Wm. Rice and Company. It was jointly agreed that additional efforts at the Whipkey mine would be futile, but further work should continue. Attempts would be made to locate the sources of air leakage from the Whipkey mine by excavating areas in the strip mine where earlier entries into the mine existed. At the same time, the project equipment would be moved to the nearby King No. 2 mine on Cucumber Run which had previously been sealed as described in Section 3.2. Air injection into the King No. 2 mine was to continue, as long as weather permitted or until the project funds expired.

6.2 King No. 2 Mine

The site and road preparation work was completed by November 21, 1968, and the trailer, engine-blower assembly and other necessary equipment were moved to the King No. 2 mine on that date. Instrument connections; however, were not completed for several days, and the engine and blower were finally put into operation on November 27, at a pumping rate of approximately 400 cfm. A slight mine pressure was apparent after several hours of pumping. This was encouraging since this was the first time that a positive pressure had been recorded during a barometric pressure rise.

The blower was operated at this pumping rate for one week. Results at the end of the one week period were generally inconclusive. Although a positive mine pressure was recorded throughout most of this time, mine pressure frequently dropped to zero for brief periods and failed to follow any definite pattern in relationship to barometric pressure changes. The recorded differential pressures are tabulated in Table 4 and are plotted in Figure 9 in the Appendix.

In an attempt to establish some type of pattern, the flow instruments were disconnected so the pumping rate could be increased. The Meriam inclined manometer, formerly used for air flow determinations, was connected to mine pressure in order to obtain a more precise reading. The blower was put into operation at an estimated pumping rate of 575 cfm on December 4, 1968. Mine pressure fluctuated for two hours and finally reached a relatively stable state at 0.05" H_2O on the manometer. The blower was run overnight at a pumping rate of approximately 575 cfm to determine what pressures could be maintained at this increased air flow. A slight differential pressure was recorded throughout the night (0.02" H_2O), during which time barometric pressure was rising.

At noon on December 5, the blower was shut-off to determine the time required for the mine pressure to return to atmospheric pressure. Differential pressure fell to zero within 30 seconds and then began to fluctuate on the manometer, sometime as high as 0.35" H_2O. The weather conditions were snowy and extremely windy and the barometric pressure was just beginning to rise. The fluctuations appeared to be directly related to wind direction and velocity, and as the wind diminished, differential mine pressure also returned to zero. Although all indications are that the mine is relatively open and free-breathing, several extensive searches failed to locate any fractures or openings into the mine.

The air flow instruments were again connected and pumping was resumed at a rate of 450 cfm. A pumping rate of 425-490 cfm was maintained during most of the period, December 5 through 12, 1968. At the end of this time, a definite pattern had still not been established.

On the assumption that the mine pressure recorder lacked the adequate sensitivity required to measure the very slight mine pressures being exerted, mine pressures were recorded from

the Meriam inclined manometer at five minute intervals over an eleven hour period on December 12, 1968. A positive differential pressure was recorded for five continuous hours at a pumping rate of approximately 490 cfm. The blower was then shut-off to determine the effect on mine pressure. The differential pressure immediately dropped to zero and remained there until pumping resumed one hour later. A positive differential pressure was then recorded for the remainder of this run. This data is shown on Table 5, and is plotted on Figure 10, both in the Appendix.

In comparing recorded differential pressure with the differential pressure observed on the inclined manometer, it was apparent that, at the marginal pressures being exerted, recorded results were not reliable. It was, therefore, decided that a 24-hour surveillance should be kept on the inclined manometer with results recorded at frequent intervals. This was to be done during a barometric pressure cycle or front; however, difficulties with the motor interfered with the original plan of operation.

The motor was repaired on December 23 and the blower was started at an air flow of approximately 575 cfm. This air flow rate was maintained over a 20-hour period. Differential mine pressures were recorded from the inclined manometer at five minute intervals. A constant positive pressure was maintained over this period, which at times rose as high as 0.28" H_2O. The average pressure during this time was approximately 0.16" H_2O. The air flow rate was then decreased to 370 cfm and operated at this rate for approximately two hours. Differential pressure during this time averaged 0.10" H_2O and did not drop below 0.09" H_2O. The pumping rate was again decreased. Air flow this time was set at approximately 325 cfm and pumping continued at this rate for two hours. Although differential pressure became marginal at this air flow rate, a positive pressure was also maintained throughout the run. This data is tabulated and plotted in Table 6 and Figure 11, respectively.

7.0 CONCLUSIONS

Attempts to develop and maintain positive differential pressures within the Whipkey deep mine by injecting air with a rotary, positive displacement blower, were only partially successful. Differential pressures up to 0.18" H_2O were developed, but could not be maintained for any extended period of time. It was later found that the mine was "free-breathing" through four feet of spoil material covering the original entries into the mine, and also through other areas where adjacent surface mining had intercepted the deep mine. Prior to the beginning of this study, it was thought that there was a minimum of ten feet of cover above these entries and that the strip mine had not intercepted the deep mine.

The differential pressures developed during periods of air injection into the Whipkey mine, as listed in Tables 1, 2 and 3, were obtained from strip chart recordings at 2-hour intervals. These readings fluctuated considerably at all air flow rates used and therefore, are not sufficiently reliable to support any conclusions. One trend was apparent,

that being an increase in differential pressure during periods of "falling" barometric pressure. The fact that significant pressures were not developed or maintained is believed to be due to the areas of the mine discussed above where air can escape to the atmosphere, thus rapidly dissipating the differential pressure.

Initial air pressurization work at the smaller King No. 2 mine also failed to produce any significant pressure as shown on Table 4 and Figure 9. The final two air injection periods produced the most reliable results of this study. During these, the differential mine pressure was measured on a sensitive and accurate inclined manometer and the readings were recorded by the field personnel. During the first of the two runs, differential pressure was recorded every five minutes for an 11-hour period on December 12, 1968, with the air flow constant at 490 cfm. Differential pressure remained steady during both slowly falling and rising barometric conditions, except for a one hour period when the motor and blower were down for maintenance. At that time, the pressure was immediately lost when air blowing stopped, and quickly developed when re-started. As shown

in Table 5 and Figure 10, differential pressure seemed to develop to a maximum of 0.03" to 0.05" H_2O at the air pumping rate of 490 cfm with very gradual changes in the barometric pressure which was generally declining from an above average "high."

In order to obtain higher air flows, all auxiliary equipment was disconnected from the motor, and air was blown into the mine at an estimated rate of 575 cfm for a 24-hour period on December 23-24, 1968. Differential pressure slowly developed to 0.20" H_2O during a gradually rising barometric pressure and remained at this level for several hours. For some unknown reason, the mine pressure began to fall off at 10:00 AM on December 24, 1968. It is thought that this decrease may be due to the increase in the rate of rise of the barometric pressure; however, the air flow rate was reduced shortly thereafter and this cannot be substantiated.

The results from the final run produced the most reliable data and it is concluded that higher gas injection rates will be required for mines which are relatively "free-breathing;" such as those used in this study. Further work

should be completed at higher gas injection rates in order to determine the rate of leakage from these mines. If pressures can be maintained at the higher injection rates, it would also be of importance to seal those areas of the Whipkey and King No. 2 mines which permit gas leakage, and determine the cost-effectiveness of such measures in relation to the inert gas method of pollution abatement.

APPENDIX

TABLE 1

DIFFERENTIAL PRESSURE (MINE OVER BAROMETRIC) RECORDED IN INCHES H_2O AT AIR FLOW RATE OF 420 CFM INTO THE WHIPKEY MINE FOR 144-HOUR PERIOD, SEPTEMBER 10-16, 1968

Date	Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.
9/10/68	12:00 N	0.00	30.15
	2:00 P.M.	0.03	"
	4:00 P.M.	0.06	"
	6:00 P.M.	0.07	"
	8:00 P.M.	0.05	"
	10:00 P.M.	0.03	"
9/11/68	12:00 M	0.03	"
	2:00 A.M.	0.01	"
	4:00 A.M.	0.01	"
	6:00 A.M.	0.00	"
	8:00 A.M.	0.00	"
	10:00 A.M.	0.00	"
	12:00 N	0.00	30.14
	2:00 P.M.	0.00	30.14
	4:00 P.M.	0.00	30.13
	6:00 P.M.	0.00	30.13
	8:00 P.M.	0.01	30.12
	10:00 P.M.	0.01	30.12
9/12/68	12:00 M	0.01	30.11
	2:00 A.M.	0.00	30.11
	4:00 A.M.	0.00	30.10
	6:00 A.M.	0.00	30.10
	8:00 A.M.	0.00	30.09
	10:00 A.M.	0.00	30.09
	12:00 N	0.00	30.06
	2:00 P.M.	0.04	30.05
	4:00 P.M.	0.08	30.04
	6:00 P.M.	0.12	30.04
	8:00 P.M.	0.08	30.03
	10:00 P.M.	0.04	30.03
9/13/68	12:00 M	0.02	30.03
	2:00 A.M.	0.00	30.03
	4:00 A.M.	0.00	30.04
	6:00 A.M.	0.06	30.06
	8:00 A.M.	0.00	30.09
	10:00 A.M.	0.00	30.12
	12:00 N	0.06	30.13
	2:00 P.M.	0.08	30.13
	4:00 P.M.	0.12	30.16
	6:00 P.M.	0.14	30.18
	8:00 P.M.	0.12	30.20
	10:00 P.M.	0.10	30.22

TABLE 1 (continued)

Date	Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.
9/14/68	12:00 M	0.06	30.22
	2:00 A.M.	0.04	30.22
	4:00 A.M.	0.02	30.22
	6:00 A.M.	0.00	30.22
	8:00 A.M.	0.00	30.22
	10:00 A.M.	0.06	30.22
	12:00 N	0.10	30.21
	2:00 P.M.	0.14	30.19
	4:00 P.M.	0.16	30.17
	6:00 P.M.	0.10	30.17
	8:00 P.M.	0.16	30.17
	10:00 P.M.	0.12	30.16
9/15/68	12:00 M	0.06	30.15
	2:00 A.M.	0.00	30.13
	4:00 A.M.	0.00	30.10
	6:00 A.M.	0.00	30.08
	8:00 A.M.	0.00	30.08
	10:00 A.M.	0.00	30.08
	12:00 N	0.00	30.08
	2:00 P.M.	0.02	30.08
	4:00 P.M.	0.04	30.08
	6:00 P.M.	0.08	30.08
	8:00 P.M.	0.14	30.09
	10:00 P.M.	0.18	30.09
9/16/68	12:00 M	0.18	30.10
	2:00 A.M.	0.18	30.13
	4:00 A.M.	0.14	30.15
	6:00 A.M.	0.10	30.15
	8:00 A.M.	0.06	30.15
	10:00 A.M.	0.04	30.15
	12:00 N	0.04	30.15

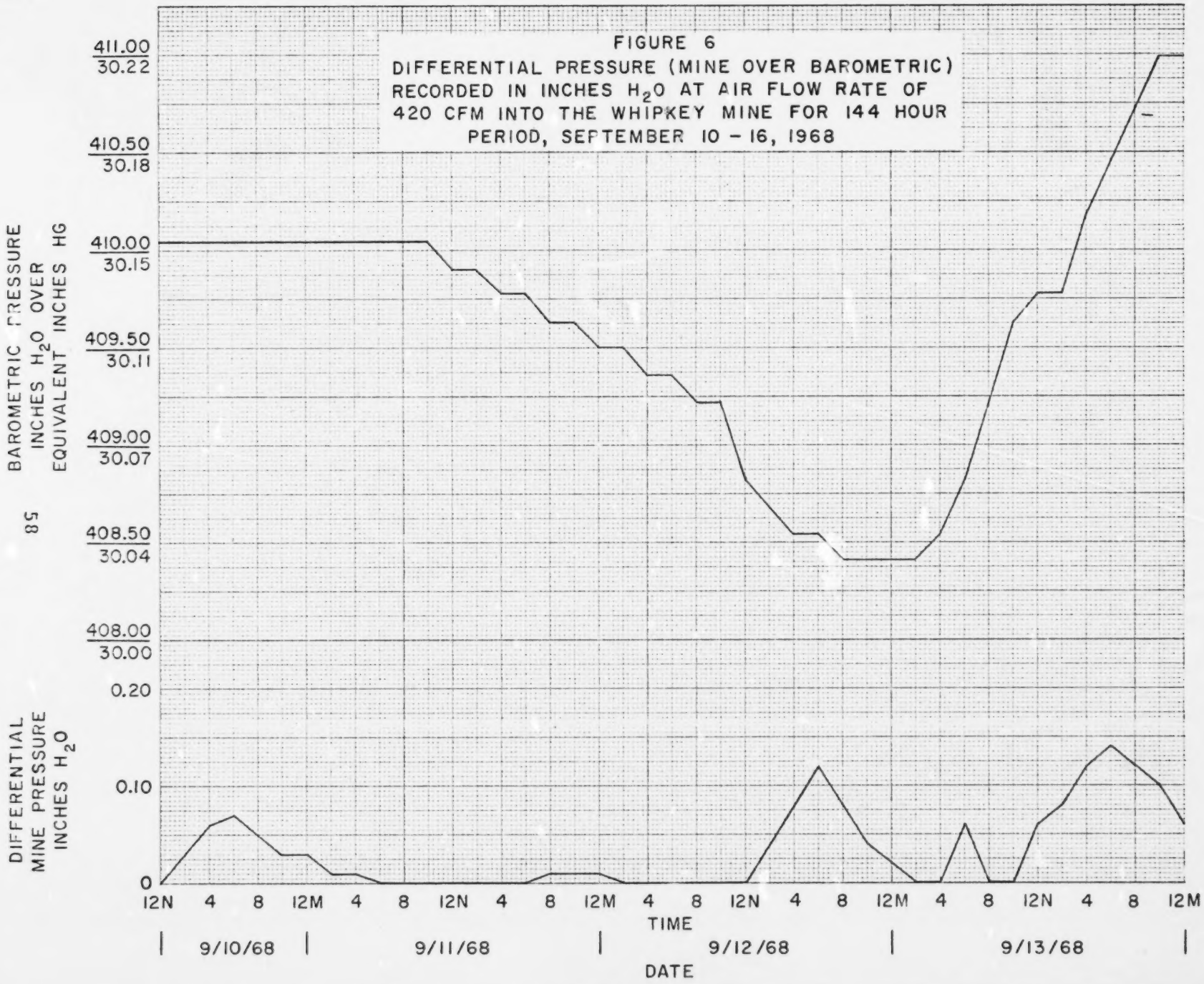


FIGURE 6
DIFFERENTIAL PRESSURE (MINE OVER BAROMETRIC) RECORDED IN INCHES H_2O AT AIR FLOW RATE OF 420 CFM INTO THE WHIPKEY MINE FOR 144 HOUR PERIOD, SEPTEMBER 10 - 16, 1968
BAROMETRIC PRESSURE INCHES H_2O OVER EQUIVALENT INCHES HG
411.00
30.22
410.50
30.18
410.00
30.15
409.50
30.11
409.00
30.07
408.50
30.04
408.00
30.00
DIFFERENTIAL MINE PRESSURE INCHES H_2O
0.20
0.10
0
12N 4 8 12M 4 8 12N 4 8 12M 4 8 12N 4 8 12M 4 8 12N 4 8 12M
TIME
9/10/68
9/11/68
9/12/68
9/13/68
DATE

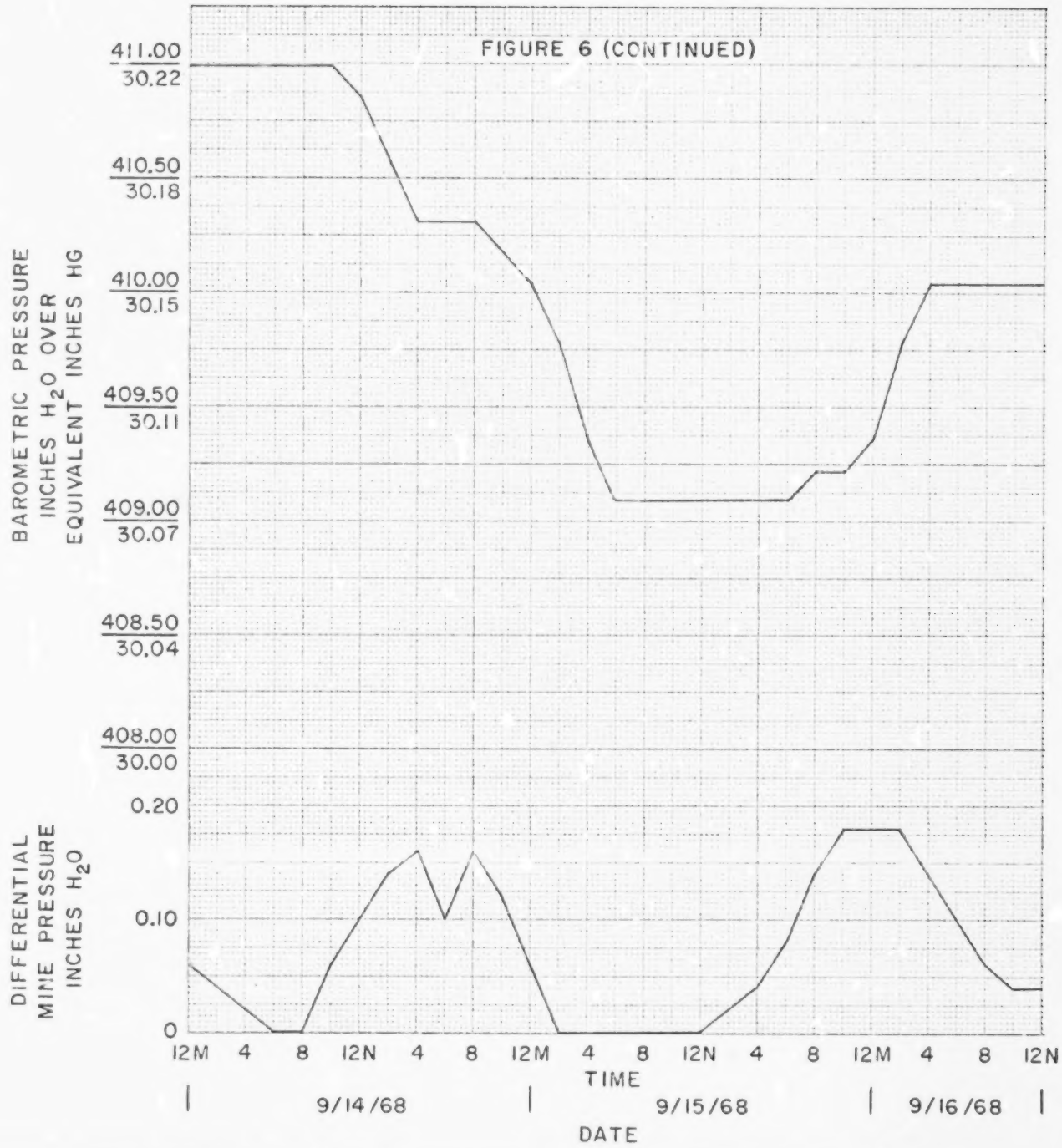


FIGURE 6 (CONTINUED)
BAROMETRIC PRESSURE
INCHES H_2O OVER
EQUIVALENT INCHES HG
411.00
30.22
410.50
30.18
410.00
30.15
409.50
30.11
409.00
30.07
408.50
30.04
408.00
30.00
DIFFERENTIAL
MINE PRESSURE
INCHES H_2O
0.20
0.10
0
12M 4 8 12N 4 8 12M 4 8 12N 4 8 12M 4 8 12N
TIME
9/14/68
9/15/68
9/16/68
DATE

TABLE 2

DIFFERENTIAL PRESSURE (MINE OVER BAROMETRIC) RECORDED IN INCHES H_2O AT VARYING AIR FLOW RATES DURING 76-HOUR PERIOD, SEPTEMBER 23-26, 1968 WHIPKEY MINE

Date	Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.	Air Flow
9/23/68	12:00 N	0.00	30.37	375 CFM
	2:00 P.M.	0.09	30.33	"
	4:00 P.M.	0.08	30.32	"
	6:00 P.M.	0.09	30.32	"
	8:00 P.M.	0.08	30.32	"
	10:00 P.M.	0.08	30.32	"
9/24/68	12:00 M	0.08	30.32	"
	2:00 A.M.	0.07	30.32	"
	4:00 A.M.	0.06	30.32	"
	6:00 A.M.	0.06	30.32	"
	8:00 A.M.	0.06	30.32	"
	10:00 A.M.	0.04	30.32	"
	12:00 N	0.02	30.30	"
	2:00 P.M.	0.10	30.25	"
	4:00 P.M.	0.15	30.23	"
	6:00 P.M.	0.14	30.22	"
	8:00 P.M.	0.09	30.22	"
	10:00 P.M.	0.04	30.22	"
9/25/68	12:00 M	0.02	30.22	"
	2:00 A.M.	0.00	30.22	"
	4:00 A.M.	0.00	30.22	000 CFM
	6:00 A.M.	0.00	30.22	"
	8:00 A.M.	0.00	30.22	"
	10:00 A.M.	0.00	30.27	"
	12:00 N	0.01	30.27	410 CFM
	2:00 P.M.	0.01	30.26	"
	4:00 P.M.	0.03	30.23	"
	6:00 P.M.	0.03	30.21	"
	8:00 P.M.	0.03	30.21	"
	10:00 P.M.	0.03	30.21	"
9/26/68	12:00 M	0.02	30.22	"
	2:00 A.M.	0.01	30.22	"
	4:00 A.M.	0.00	30.22	"
	6:00 A.M.	0.00	30.22	"
	8:00 A.M.	0.00	30.24	"
	10:00 A.M.	0.00	30.25	"
	12:00 N	0.00	30.25	"
	2:00 P.M.	0.00	30.25	"
	4:00 P.M.	0.00	30.24	"

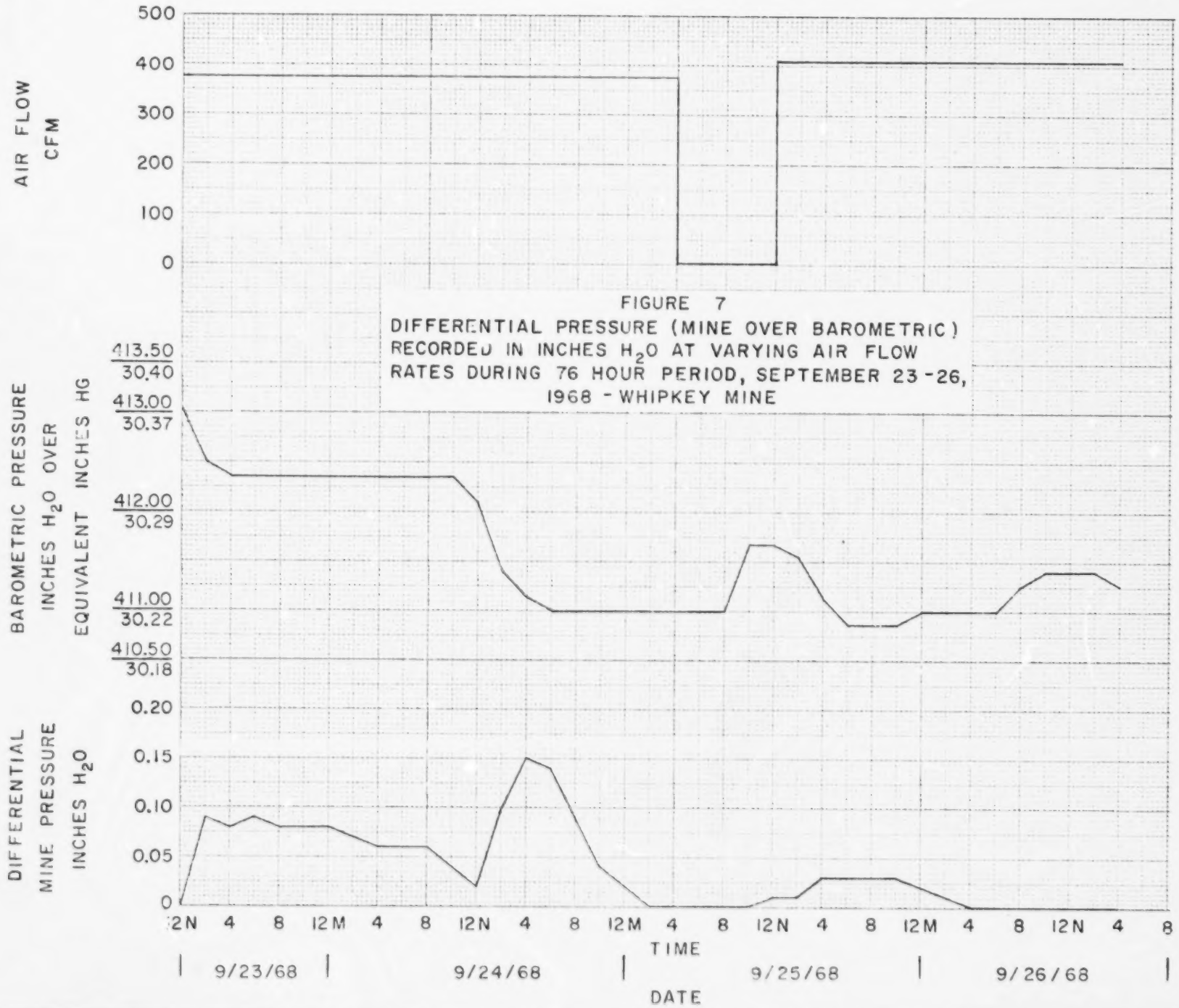


FIGURE 7
DIFFERENTIAL PRESSURE (MINE OVER BAROMETRIC) RECORDED IN INCHES H_2O AT VARYING AIR FLOW RATES DURING 76 HOUR PERIOD, SEPTEMBER 23-26, 1968 - WHIPKEY MINE

TABLE 3

DIFFERENTIAL PRESSURE (MINE OVER BAROMETRIC) RECORDED IN INCHES H_2O AT CONSTANT AIR FLOW RATE OF 500 CFM DURING 104-HOUR PERIOD, NOVEMBER 1-5, 1968, AT SLOWLY FALLING BAROMETRIC PRESSURE
WHIPKEY MINE

Date	Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.
11/01/68	10:00 A.M.	0.00	30.35
	12:00 N	0.02	30.35
	2:00 P.M.	0.08	30.32
	4:00 P.M.	0.08	30.31
	6:00 P.M.	0.06	30.30
	8:00 P.M.	0.03	30.30
	10:00 P.M.	0.00	30.30
11/02/68	12:00 M	0.00	30.30
	2:00 A.M.	0.00	30.30
	4:00 A.M.	0.00	30.30
	6:00 A.M.	0.00	30.30
	8:00 A.M.	0.00	30.30
	10:00 A.M.	0.00	30.30
	12:00 N	0.03	30.30
	2:00 P.M.	0.06	30.28
	4:00 P.M.	0.06	30.27
	6:00 P.M.	0.04	30.27
	8:00 P.M.	0.00	30.27
	10:00 P.M.	0.00	30.27
11/03/68	12:00 M	0.00	30.27
	2:00 A.M.	0.00	30.27
	4:00 A.M.	0.00	30.27
	6:00 A.M.	0.00	30.27
	8:00 A.M.	0.00	30.27
	10:00 A.M.	0.00	30.27
	12:00 N	0.00	30.27
	2:00 P.M.	0.00	30.27
	4:00 P.M.	0.00	30.27
	6:00 P.M.	0.00	30.27
	8:00 P.M.	0.00	30.27
	10:00 P.M.	0.00	30.27
11/04/68	12:00 M	0.00	30.27
	2:00 A.M.	0.00	30.27
	4:00 A.M.	0.00	30.27
	6:00 A.M.	0.00	30.27
	8:00 A.M.	0.00	30.27
	10:00 A.M.	0.00	30.27
	12:00 N	0.00	30.27
	2:00 P.M.	0.00	30.27
	4:00 P.M.	0.00	30.27
	6:00 P.M.	0.00	30.27
	8:00 P.M.	0.00	30.27
	10:00 P.M.	0.00	30.25

TABLE 3 (continued)

Date	Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.
11/05/68	12:00 M	0.00	30.25
	2:00 A.M.	0.00	30.20
	4:00 A.M.	0.00	30.20
	6:00 A.M.	0.00	30.20
	8:00 A.M.	0.00	30.16
	10:00 A.M.	0.00	30.18
	12:00 N	0.00	30.17
	2:00 P.M.	0.02	30.16
	4:00 P.M.	0.03	30.15
	6:00 P.M.	0.03	30.15

FIGURE 8
DIFFERENTIAL PRESSURE (MINE OVER BAROMETRIC) RECORDED IN INCHES H_2O AT CONSTANT AIR FLOW RATE OF 500 CFM DURING 104 HOUR PERIOD, NOVEMBER 1-5, 1968 AT SLOWLY FALLING BAROMETRIC PRESSURE – WHIPKEY MINE

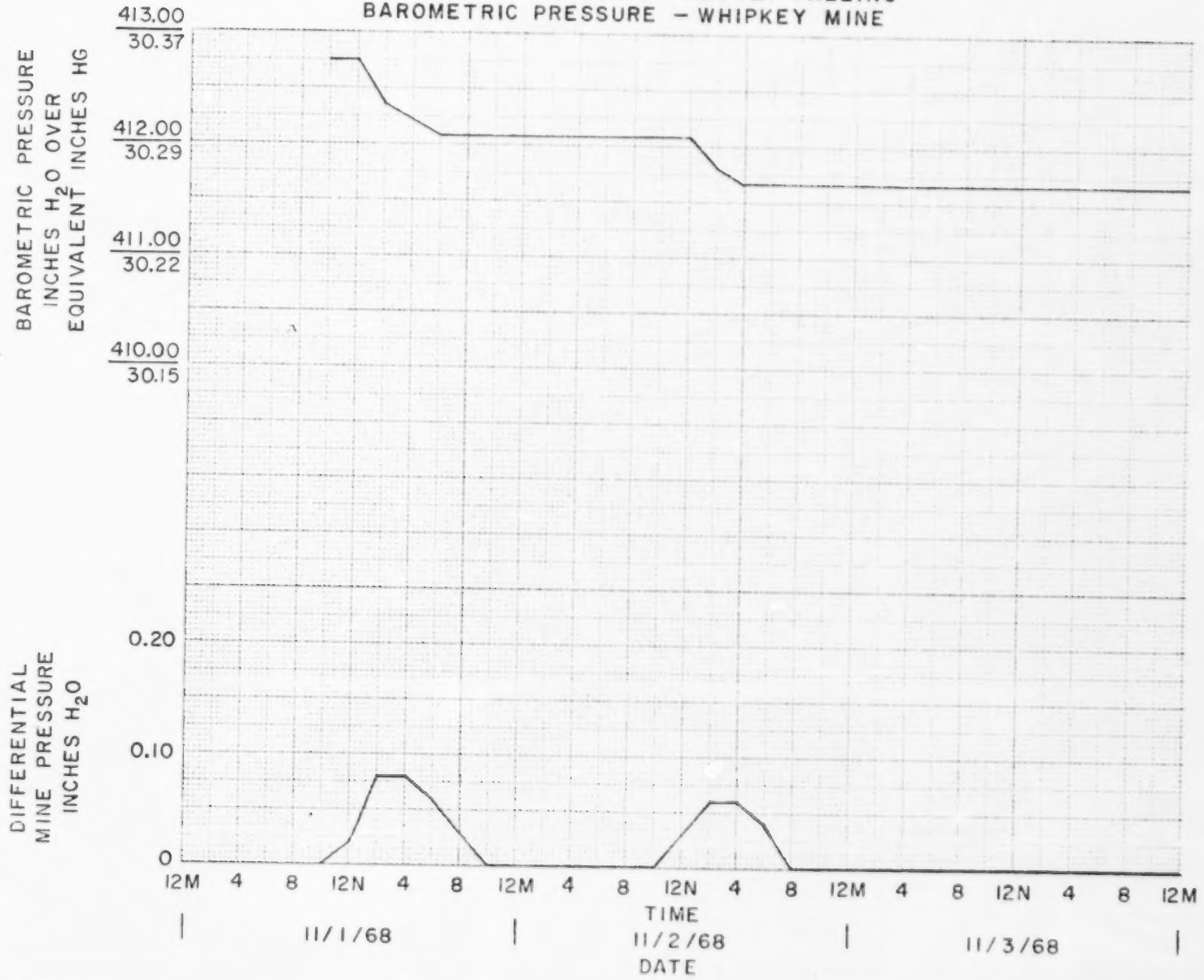


FIGURE 8 (CONTINUED)
BAROMETRIC PRESSURE
INCHES H2O OVER
EQUIVALENT INCHES HG
413.00
30.37
412.00
30.29
411.00
30.22
410.00
30.15
DIFFERENTIAL
MINE PRESSURE
INCHES H2O
0.20
0.10
0
12M 4 8 12N 4 8 12M 4 8 12N 4 8 12M
TIME
11/4/68
DATE
11/5/68

TABLE 4

DIFFERENTIAL PRESSURE (MINE OVER BAROMETRIC) RECORDED IN INCHES H_2O AT VARYING AIR FLOW RATES OVER A 16-DAY PERIOD, NOVEMBER 27 TO DECEMBER 14, 1968, DURING A COMPLETE BAROMETRIC CYCLE
KING NO. 2 MINE

Date	Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.	Air Flow
11/27/68	2:00 P.M.	.05	30.41	400 CFM
	4:00 P.M.	.06	30.42	400 CFM
	6:00 P.M.	.02	30.42	425 CFM
	8:00 P.M.	.01	30.42	"
	10:00 P.M.	.00	30.42	"
11/28/68	12:00 M	.00	30.42	"
	2:00 A.M.	.00	30.40	"
	4:00 A.M.	.00	30.38	"
	6:00 A.M.	.00	30.35	"
	8:00 A.M.	.00	30.33	"
	10:00 A.M.	.00	30.31	"
	12:00 N	.01	30.22	"
	2:00 P.M.	.04	30.12	"
	4:00 P.M.	.05	30.08	"
	6:00 P.M.	.06	30.02	"
	8:00 P.M.	.05	30.00	"
	10:00 P.M.	.05	30.00	"
11/29/68	12:00 M	.05	30.02	"
	2:00 A.M.	.04	30.04	"
	4:00 A.M.	.03	30.08	"
	6:00 A.M.	.02	30.12	"
	8:00 A.M.	.01	30.18	"
	10:00 A.M.	.00	30.25	"
	12:00 N	.00	30.28	"
	2:00 P.M.	.00	30.36	"
	4:00 P.M.	.01	30.38	"
	6:00 P.M.	.00	30.41	"
	8:00 P.M.	.00	30.43	"
	10:00 P.M.	.00	30.44	"
11/30/68	12:00 M	.01	30.46	"
	2:00 A.M.	.00	30.48	"
	4:00 A.M.	.02	30.50	"
	6:00 A.M.	.02	30.51	"
	8:00 A.M.	.02	30.54	"
	10:00 A.M.	.02	30.57	"
	12:00 N	.01	30.59	"
	2:00 P.M.	.01	30.59	"
	4:00 P.M.	.01	30.59	"
	6:00 P.M.	.01	30.59	"
	8:00 P.M.	.02	30.60	"
	10:00 P.M.	.02	30.60	"

TABLE 4 (continued)

Date	Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.	Air Flow
12/01/68	12:00 M	.01	30.62	415 CFM
	2:00 A.M.	.02	30.61	"
	4:00 A.M.	.03	30.59	"
	6:00 A.M.	.03	30.56	"
	8:00 A.M.	.02	30.54	"
	10:00 A.M.	.02	30.52	"
	12:00 N	.02	30.50	"
	2:00 P.M.	.02	30.42	"
	4:00 P.M.	.01	30.35	"
	6:00 P.M.	.01	30.28	"
	8:00 P.M.	.01	30.28	"
	10:00 P.M.	.01	30.29	"
12/02/68	12:00 M	.01	30.30	"
	2:00 A.M.	.01	30.30	"
	4:00 A.M.	.01	30.30	"
	6:00 A.M.	.02	30.30	"
	8:00 A.M.	.01	30.31	"
	10:00 A.M.	.02	30.31	"
	12:00 N	.03	30.31	"
	2:00 P.M.	.02	30.32	"
	4:00 P.M.	.03	30.32	"
	6:00 P.M.	.02	30.32	"
	8:00 P.M.	.01	30.33	"
	10:00 P.M.	.01	30.33	"
12/03/68	12:00 M	.01	30.33	"
	2:00 A.M.	.00	30.34	"
	4:00 A.M.	.01	30.34	"
	6:00 A.M.	.01	30.34	"
	8:00 A.M.	.01	30.34	"
	10:00 A.M.	.00	30.33	"
	12:00 N	.00	30.33	"
	2:00 P.M.	.00	30.30	"
	4:00 P.M.	.00	30.25	"
	6:00 P.M.	.00	30.20	"
	8:00 P.M.	.00	30.17	"
	10:00 P.M.	.02	30.13	"
12/04/68	12:00 M	.02	30.04	"
	2:00 A.M.	.01	30.00	"
	4:00 A.M.	.01	29.95	"
	6:00 A.M.	.00	29.87	"
	8:00 A.M.	.01	29.83	"
	10:00 A.M.	.01	29.82	"
	12:00 N	.00	29.77	575 CFM
	2:00 P.M.	.00	29.78	"
	4:00 P.M.	.02	29.80	"
	6:00 P.M.	.02	29.84	"
	8:00 P.M.	.01	29.87	"
	10:00 P.M.	.01	29.88	"

TABLE 4 (continued)

Date	Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.	Air Flow
12/05/68	12:00 M	.02	29.89	575 CFM
	2:00 A.M.	.02	29.89	"
	4:00 A.M.	.01	29.88	"
	6:00 A.M.	.02	29.85	"
	8:00 A.M.	.01	29.82	"
	10:00 A.M.	.02	29.80	"
	12:00 N		29.85	000 CFM
	2:00 P.M.		29.87	000 CFM
	4:00 P.M.	.03	29.90	450 CFM
	6:00 P.M.	.01	29.94	"
	8:00 P.M.	.02	30.01	"
	10:00 P.M.	.03	30.08	"
12/06/68	12:00 M	.03	30.12	"
	2:00 A.M.	.02	30.14	"
	4:00 A.M.	.03	30.17	"
	6:00 A.M.	.02	30.18	"
	8:00 A.M.	.03	30.20	"
	10:00 A.M.	.03	30.25	"
	12:00 N	.07	30.30	325 CFM
	2:00 P.M.	.06	30.27	"
	4:00 P.M.	.05	30.28	"
	6:00 P.M.	.01	30.29	"
	8:00 P.M.	.00	30.30	"
	10:00 P.M.	.00	30.31	"
12/07/68	12:00 M	.00	30.31	"
	2:00 A.M.	.00	30.32	"
	4:00 A.M.	.00	30.32	"
	6:00 A.M.	.01	30.32	"
	8:00 A.M.	.00	30.32	"
	10:00 A.M.	.01	30.32	425 CFM
	12:00 N	.00	30.32	"
	2:00 P.M.	.00	30.32	"
	4:00 P.M.	.00	30.32	"
	6:00 P.M.	.00	30.32	"
	8:00 P.M.	.00	30.32	"
	10:00 P.M.	.00	30.32	"
12/08/68	12:00 M	.00	30.33	"
	2:00 A.M.	.00	30.33	"
	4:00 A.M.	.00	30.33	"
	6:00 A.M.	.00	30.33	"
	8:00 A.M.	.01	30.33	"
	10:00 A.M.	.00	30.35	"
	12:00 N	.00	30.43	"
	2:00 P.M.	.00	30.43	"
	4:00 P.M.	.00	30.47	"

TABLE 4 (continued)

Date	Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.	Air Flow
12/08/68	6:00 P.M.	.01	30.49	425 CFM
	8:00 P.M.	.01	30.51	"
	10:00 P.M.	.01	30.52	"
12/09/68	12:00 M	.00	30.52	"
	2:00 A.M.	.01	30.54	"
	4:00 A.M.	.01	30.57	"
	6:00 A.M.	.00	30.59	"
	8:00 A.M.	.01	30.60	"
	10:00 A.M.	.01	30.62	"
	12:00 N	.04	30.63	"
	2:00 P.M.	.06	30.62	000 CFM
	4:00 P.M.	.02	30.62	425 CFM
	6:00 P.M.	.01	30.63	"
	8:00 P.M.	.00	30.65	000 CFM
	10:00 P.M.	.00	30.66	"
12/10/68	12:00 M	.00	30.67	"
	2:00 A.M.	.00	30.68	"
	4:00 A.M.	.00	30.69	"
	6:00 A.M.	.00	30.70	"
	8:00 A.M.	.00	30.73	"
	10:00 A.M.	.00	30.78	"
	12:00 N	.00	30.76	"
	2:00 P.M.	.00	30.70	"
	4:00 P.M.	.00	30.70	490 CFM
	6:00 P.M.	.01	30.70	"
	8:00 P.M.	.03	30.70	"
	10:00 P.M.	.03	30.70	"
12/11/68	12:00 M	.02	30.70	"
	2:00 A.M.	.01	30.70	"
	4:00 A.M.	.01	30.70	"
	6:00 A.M.	.00	30.69	"
	8:00 A.M.	.00	30.69	"
	10:00 A.M.	Chart Stuck	30.68	"
	12:00 N	Chart Stuck	30.64	"
	2:00 P.M.	Chart Stuck	30.59	"
	4:00 P.M.	Chart Stuck	30.58	"
	6:00 P.M.	Chart Stuck	30.57	"
	8:00 P.M.	Chart Stuck	30.55	"
	10:00 P.M.	Chart Stuck	30.55	"
12/12/68	12:00 M	Chart Stuck	30.54	"
	2:00 A.M.	Chart Stuck	30.53	"
	4:00 A.M.	Chart Stuck	30.53	"
	6:00 A.M.	Chart Stuck	30.53	"
	8:00 A.M.	Chart Stuck	30.54	"
	10:00 A.M.	.08	30.53	"

TABLE 4 (continued)

Date	Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.	Air Flow
12/12/68	12:00 N	.05	30.48	490 CFM
	2:00 P.M.	.10	30.43	"
	4:00 P.M.	.10	30.42	"
	6:00 P.M.	.09	30.43	"
	8:00 P.M.	.05	30.45	"
	10:00 P.M.	.03	30.42	"
12/13/68	12:00 M	.02	30.38	"
	2:00 A.M.	.01	30.33	"
	4:00 A.M.	.01	30.32	"
	6:00 A.M.	.01	30.30	"
	8:00 A.M.	0.00	30.30	575 CFM
	10:00 A.M.	0.00	30.28	"
	12:00 N	0.01	30.27	"
	2:00 P.M.	0.03	30.22	"
	4:00 P.M.	0.03	30.20	425 CFM
	6:00 P.M.	0.03	30.21	"
	8:00 P.M.	0.02	30.21	"
	10:00 P.M.	0.02	30.21	"
12/14/68	12:00 M	0.00	30.21	"

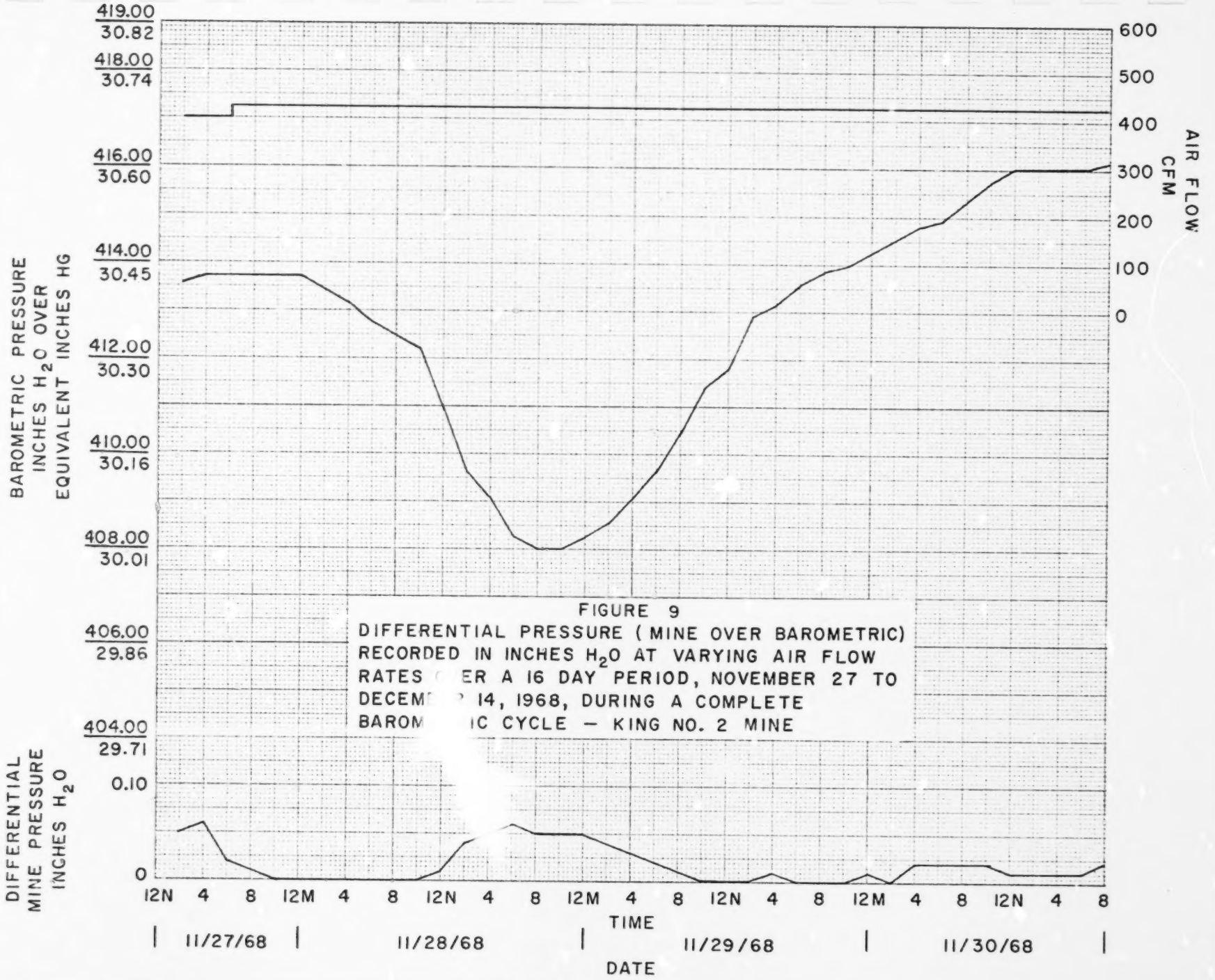


FIGURE 9
DIFFERENTIAL PRESSURE (MINE OVER BAROMETRIC) RECORDED IN INCHES H_2O AT VARYING AIR FLOW RATES (ER A 16 DAY PERIOD, NOVEMBER 27 TO DECEM 14, 1968, DURING A COMPLETE BAROM IC CYCLE — KING NO. 2 MINE

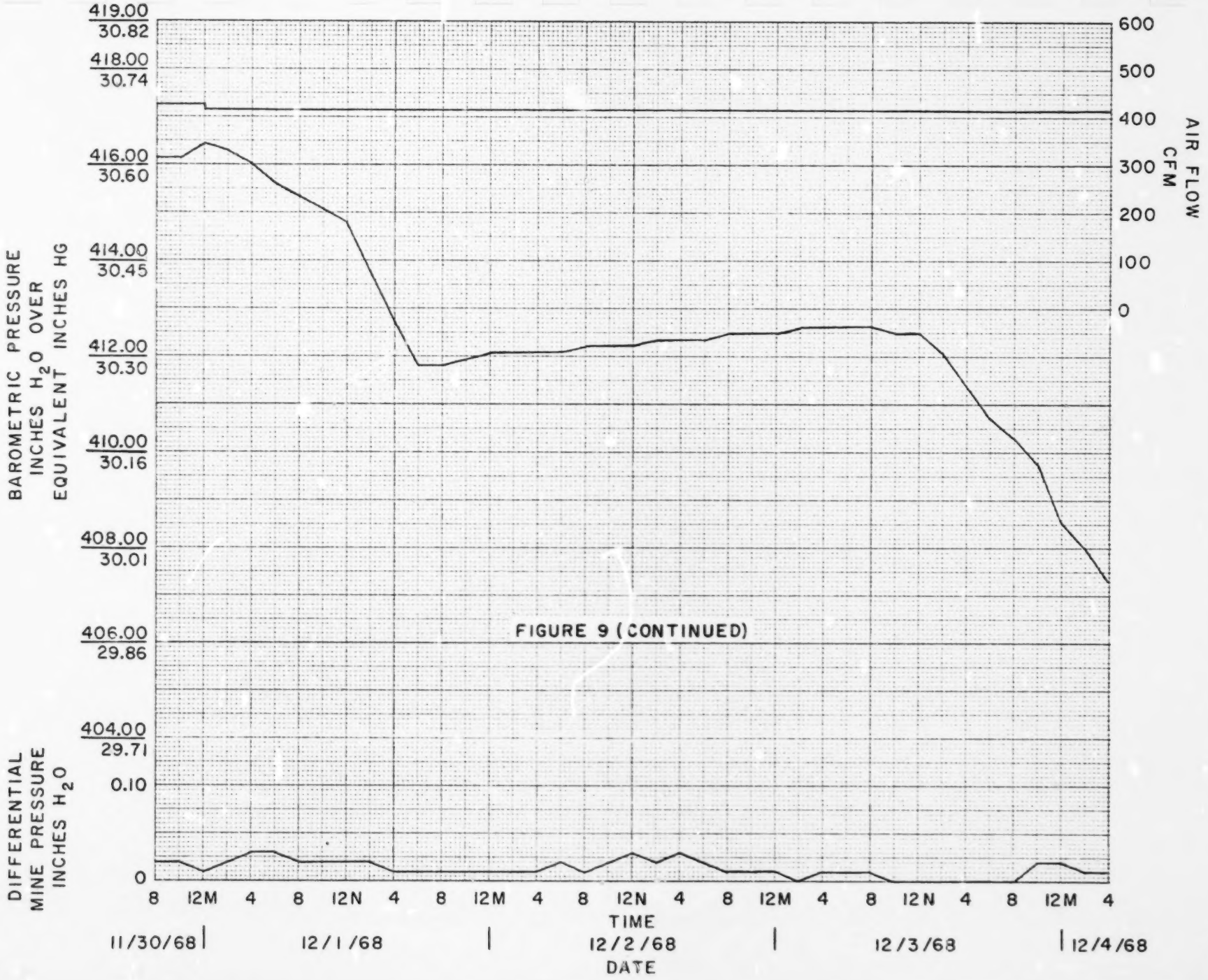


FIGURE 9 (CONTINUED)

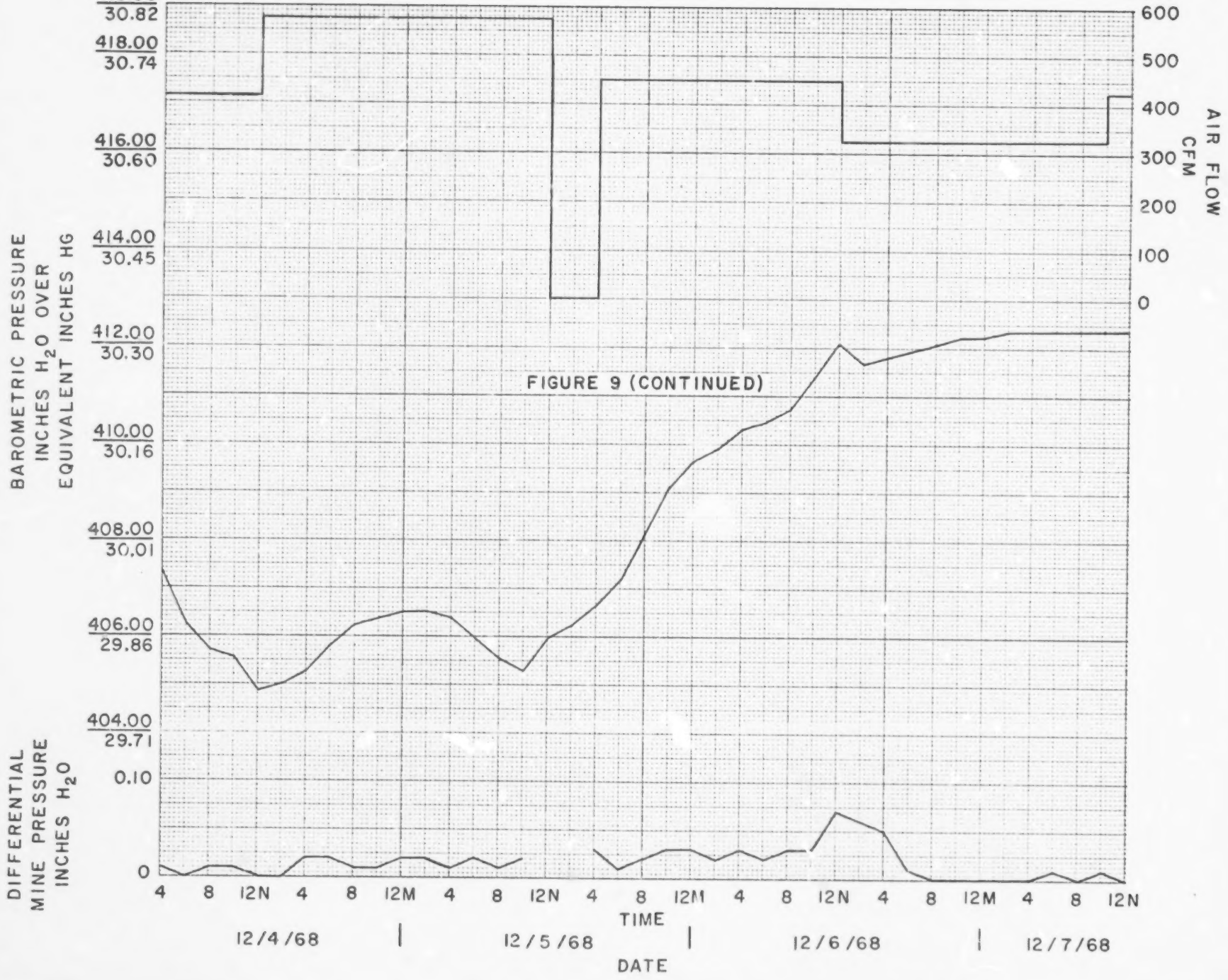


FIGURE 9 (CONTINUED)

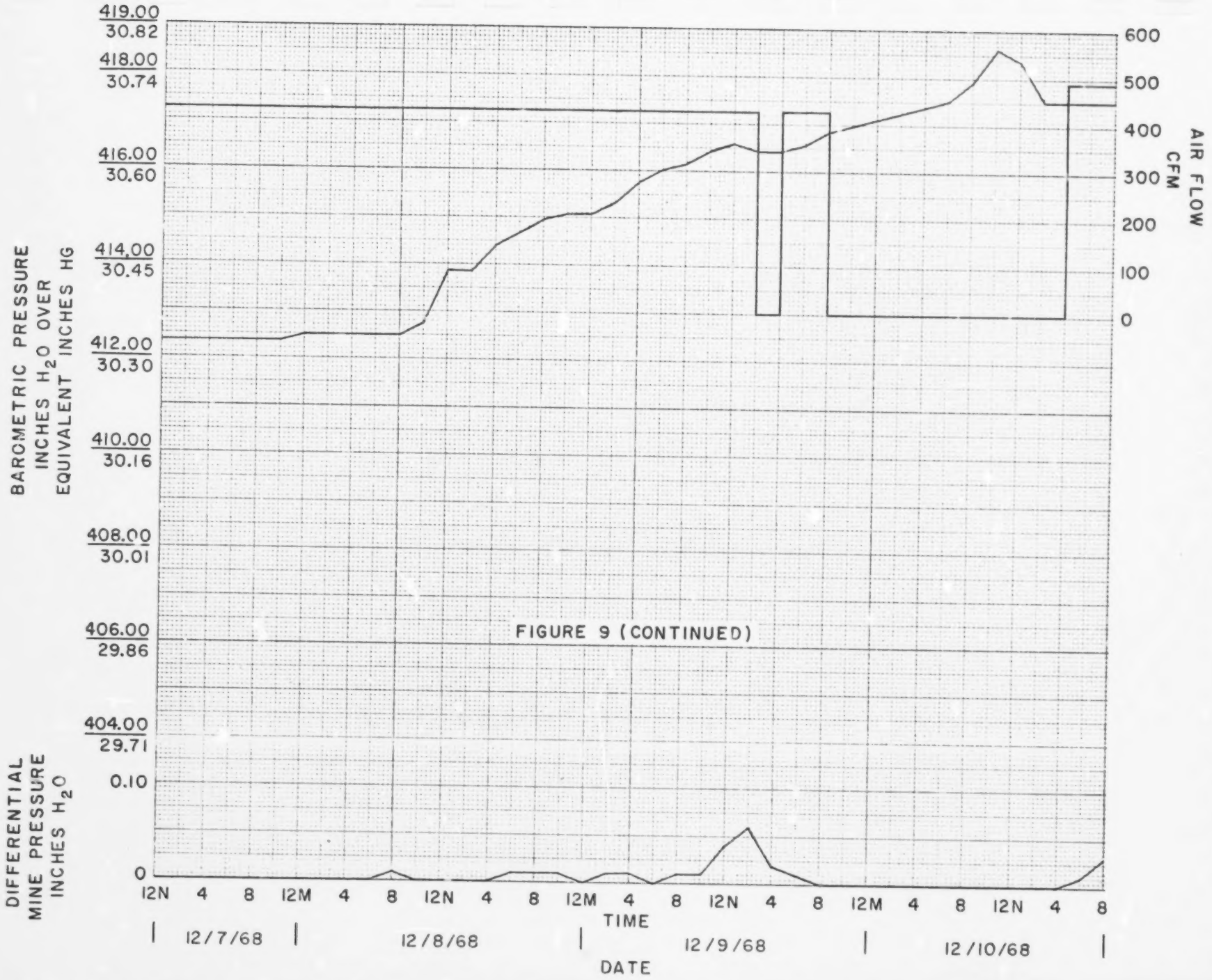


FIGURE 9 (CONTINUED)

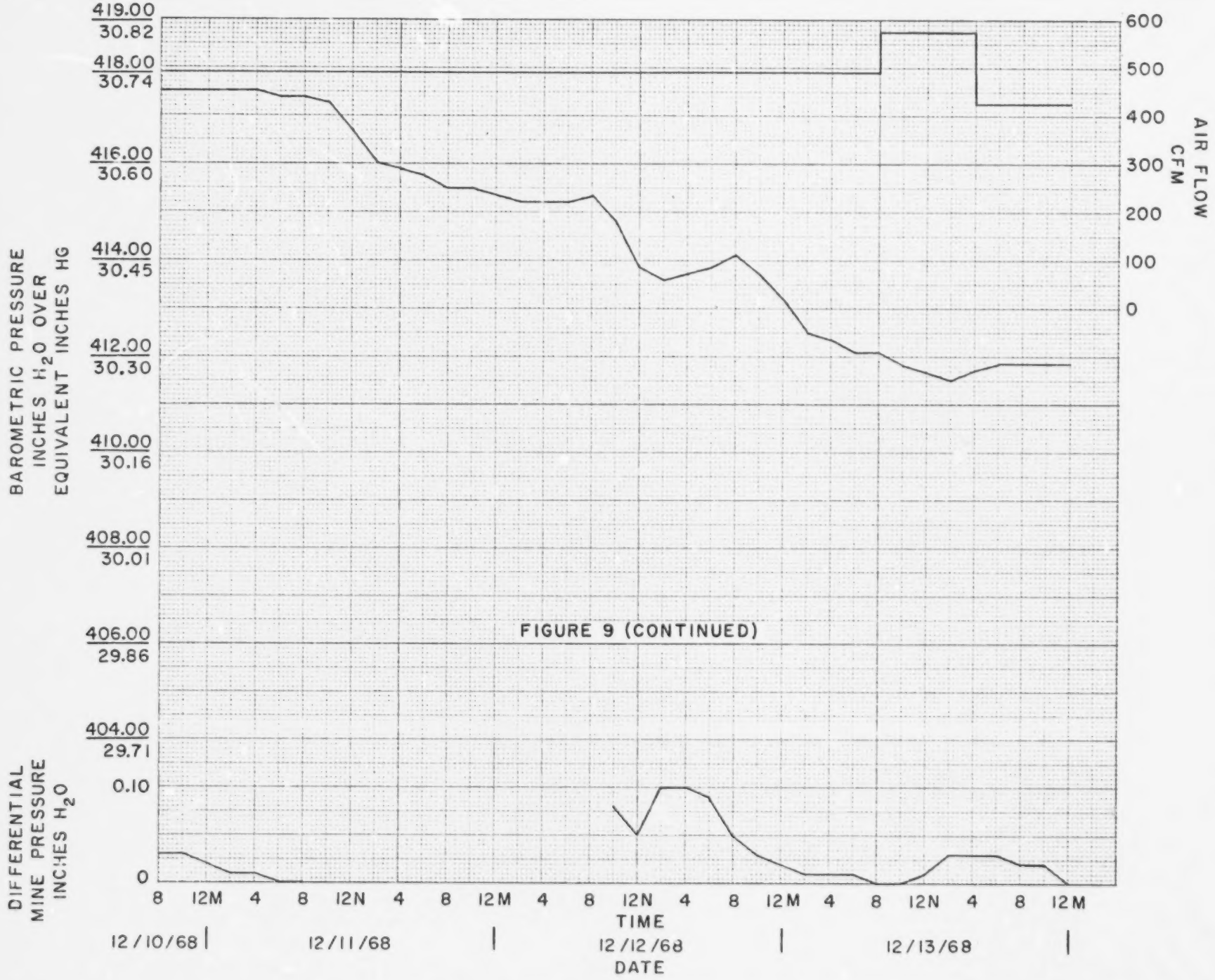


FIGURE 9 (CONTINUED)

TABLE 5

DIFFERENTIAL PRESSURE (MINE OVER BAROMETRIC) RECORDED IN INCHES H_2O FROM THE INCLINED MANOMETER AT 5 MINUTE INTERVALS DURING AN 11-HOUR PERIOD ON DECEMBER 12, 1968, WITH A CONSTANT AIR FLOW OF 490 CFM INTO THE KING NO. 2 MINE

Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.	Air Flow
9:00 A.M.	0.03	30.53	490 CFM
9:05 A.M.	0.03	30.53	"
9:10 A.M.	0.03	30.53	"
9:15 A.M.	0.04	30.53	"
9:20 A.M.	0.05	30.53	"
9:25 A.M.	0.04	30.53	"
9:30 A.M.	0.04	30.53	"
9:35 A.M.	0.05	30.53	"
9:40 A.M.	0.05	30.53	"
9:45 A.M.	0.04	30.53	"
9:50 A.M.	0.03	30.53	"
9:55 A.M.	0.05	30.53	"
10:00 A.M.	0.04	30.53	"
10:05 A.M.	0.04	30.53	"
10:10 A.M.	0.04	30.53	"
10:15 A.M.	0.04	30.53	"
10:20 A.M.	0.04	30.52	"
10:25 A.M.	0.04	30.52	"
10:30 A.M.	0.04	30.52	"
10:35 A.M.	0.04	30.52	"
10:40 A.M.	0.04	30.52	"
10:45 A.M.	0.05	30.51	"
10:50 A.M.	0.03	30.51	"
10:55 A.M.	0.04	30.51	"
11:00 A.M.	0.04	30.51	"
11:05 A.M.	0.04	30.50	"
11:10 A.M.	0.04	30.50	"
11:15 A.M.	0.04	30.50	"
11:20 A.M.	0.04	30.49	"
11:25 A.M.	0.04	30.49	"
11:30 A.M.	0.04	30.49	"
11:35 A.M.	0.04	30.49	"
11:40 A.M.	0.04	30.48	"
11:45 A.M.	0.04	30.48	"
11:50 A.M.	0.04	30.48	"
11:55 A.M.	0.04	30.48	"
12:00 N	0.04	30.48	"
12:05 P.M.	0.04	30.47	"
12:10 P.M.	0.04	30.47	"
12:15 P.M.	0.04	30.47	"
12:20 P.M.	0.04	30.46	"
12:25 P.M.	0.04	30.46	"
12:30 P.M.	0.04	30.46	"

TABLE 5 (continued)

Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.	Air Flow
12:35 P.M.	0.03	30.46	490 CFM
12:40 P.M.	0.03	30.46	"
12:45 P.M.	0.04	30.46	"
12:50 P.M.	0.03	30.46	"
12:55 P.M.	0.04	30.46	"
1:00 P.M.	0.04	30.45	"
1:05 P.M.	0.04	30.45	"
1:10 P.M.	0.04	30.45	"
1:15 P.M.	0.04	30.45	"
1:20 P.M.	0.04	30.45	"
1:25 P.M.	0.03	30.45	"
1:30 P.M.	0.04	30.44	"
1:35 P.M.	0.04	30.44	"
1:40 P.M.	0.05	30.44	"
1:45 P.M.	0.04	30.43	"
1:50 P.M.	0.04	30.43	"
1:55 P.M.	0.04	30.43	"
2:00 P.M.	0.03	30.43	"
2:05 P.M.	0.00	30.42	000 CFM
2:10 P.M.	0.00	30.42	"
2:15 P.M.	0.00	30.42	"
2:20 P.M.	0.00	30.42	"
2:25 P.M.	0.00	30.42	"
2:30 P.M.	0.00	30.41	"
2:35 P.M.	0.00	30.41	"
2:40 P.M.	0.00	30.41	"
2:45 P.M.	0.00	30.41	"
2:50 P.M.	0.00	30.41	"
2:55 P.M.	0.00	30.41	"
3:00 P.M.	0.00	30.41	"
3:05 P.M.	0.03	30.42	490 CFM
3:10 P.M.	0.03	30.42	"
3:15 P.M.	0.03	30.42	"
3:20 P.M.	0.03	30.42	"
3:25 P.M.	0.03	30.42	"
3:30 P.M.	0.03	30.42	"
3:35 P.M.	0.03	30.42	"
3:40 P.M.	0.03	30.42	"
3:45 P.M.	0.03	30.42	"
3:50 P.M.	0.03	30.42	"
3:55 P.M.	0.03	30.42	"
4:00 P.M.	0.03	30.42	"
4:05 P.M.	0.03	30.43	"
4:10 P.M.	0.03	30.43	"
4:15 P.M.	0.03	30.43	"
4:20 P.M.	0.03	30.43	"
4:25 P.M.	0.03	30.43	"
4:30 P.M.	0.03	30.43	"

TABLE 5 (continued)

Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.	Air Flow
4:35 P.M.	0.03	30.43	490 CFM
4:40 P.M.	0.03	30.43	"
4:45 P.M.	0.03	30.43	"
4:50 P.M.	0.03	30.43	"
4:55 P.M.	0.03	30.43	"
5:00 P.M.	0.03	30.43	"
5:05 P.M.	0.03	30.43	"
5:10 P.M.	0.03	30.43	"
5:15 P.M.	0.03	30.43	"
5:20 P.M.	0.03	30.43	"
5:25 P.M.	0.03	30.43	"
5:30 P.M.	0.03	30.43	"
5:35 P.M.	0.03	30.44	"
5:40 P.M.	0.03	30.44	"
5:45 P.M.	0.03	30.44	"
5:50 P.M.	0.03	30.44	"
5:55 P.M.	0.03	30.44	"
6:00 P.M.	0.03	30.44	"
6:05 P.M.	0.03	30.44	"
6:10 P.M.	0.03	30.44	"
6:15 P.M.	0.03	30.44	"
6:20 P.M.	0.03	30.44	"
6:25 P.M.	0.03	30.44	"
6:30 P.M.	0.03	30.44	"
6:35 P.M.	0.03	30.44	"
6:40 P.M.	0.03	30.44	"
6:45 P.M.	0.03	30.45	"
6:50 P.M.	0.03	30.45	"
6:55 P.M.	0.03	30.45	"
7:00 P.M.	0.03	30.45	"
7:05 P.M.	0.03	30.45	"
7:10 P.M.	0.03	30.45	"
7:15 P.M.	0.03	30.45	"
7:20 P.M.	0.03	30.45	"
7:25 P.M.	0.03	30.45	"
7:30 P.M.	0.03	30.45	"
7:35 P.M.	0.03	30.45	"
7:40 P.M.	0.03	30.45	"
7:45 P.M.	0.03	30.45	"
7:50 P.M.	0.03	30.45	"
7:55 P.M.	0.03	30.45	"
8:00 P.M.	0.03	30.45	"

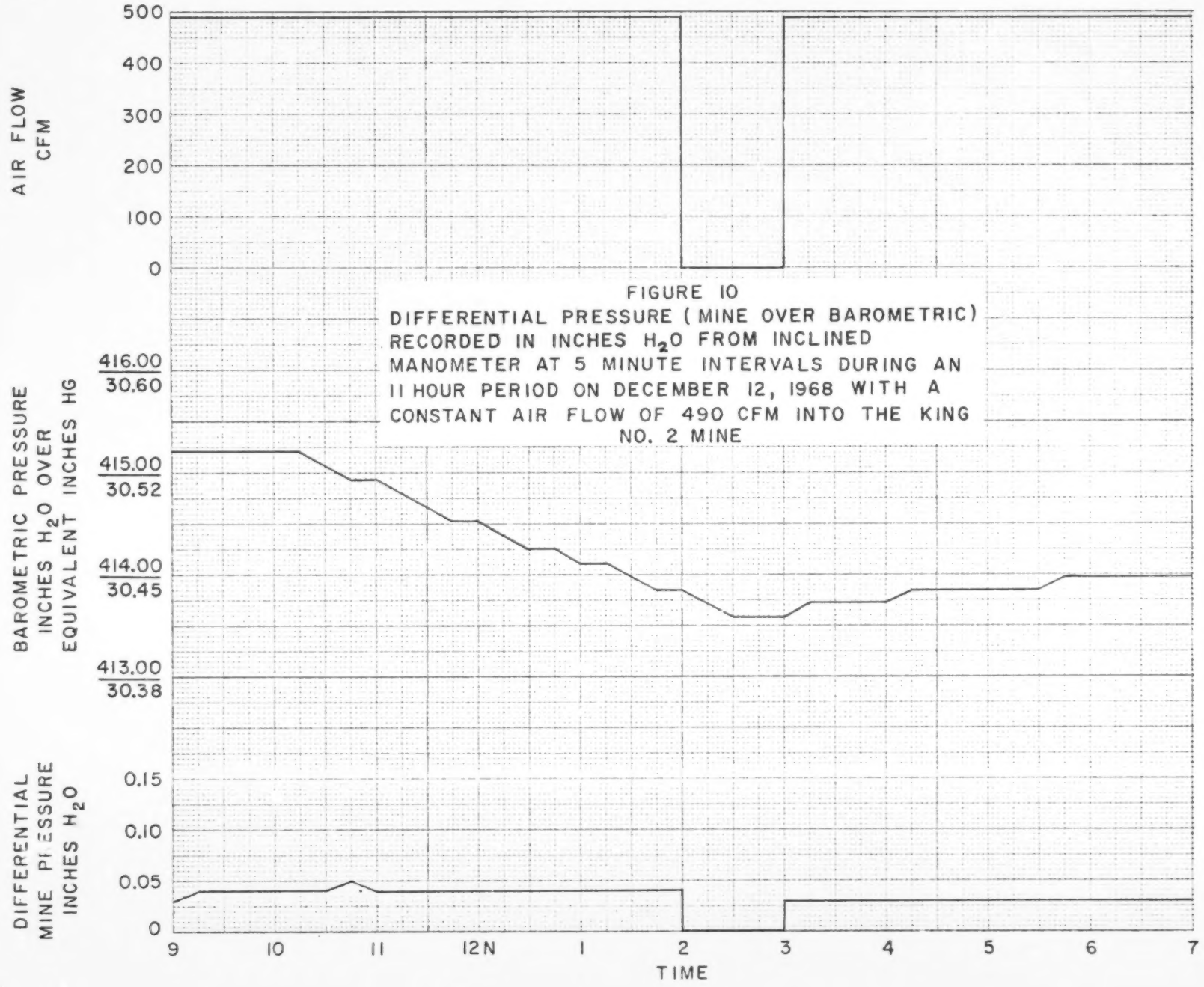


FIGURE 10
DIFFERENTIAL PRESSURE (MINE OVER BAROMETRIC) RECORDED IN INCHES H_2O FROM INCLINED MANOMETER AT 5 MINUTE INTERVALS DURING AN 11 HOUR PERIOD ON DECEMBER 12, 1968 WITH A CONSTANT AIR FLOW OF 490 CFM INTO THE KING NO. 2 MINE

TABLE 6

DIFFERENTIAL PRESSURE (MINE OVER BAROMETRIC) RECORDED IN INCHES H_2O FROM THE INCLINED MANOMETER AT 5 MINUTE INTERVALS DURING A 24-HOUR PERIOD, DECEMBER 23-24, 1968, WITH A CONSTANT AIR FLOW OF 575 CFM INTO THE KING NO. 2 MINE

Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.	Air Flow
3:15 P.M.	0.00	29.96	575 CFM
3:20 P.M.	0.01	29.96	"
3:25 P.M.	0.01	29.96	"
3:30 P.M.	0.01	29.96	"
3:35 P.M.	0.01	29.96	"
3:40 P.M.	0.01	29.96	"
3:45 P.M.	0.01	29.97	"
3:50 P.M.	0.01	29.97	"
3:55 P.M.	0.01	29.97	"
4:00 P.M.	0.01	29.97	"
4:05 P.M.	0.02	29.97	"
4:10 P.M.	0.02	29.97	"
4:15 P.M.	0.02	29.98	"
4:20 P.M.	0.03	29.98	"
4:25 P.M.	0.03	29.98	"
4:30 P.M.	0.03	29.98	"
4:35 P.M.	0.03	29.98	"
4:40 P.M.	0.03	29.98	"
4:45 P.M.	0.03	29.98	"
4:50 P.M.	0.03	29.98	"
4:55 P.M.	0.03	29.98	"
5:00 P.M.	0.03	29.99	"
5:05 P.M.	0.03	29.99	"
5:10 P.M.	0.03	29.99	"
5:15 P.M.	0.03	29.99	"
5:20 P.M.	0.03	29.99	"
5:25 P.M.	0.02	29.99	"
5:30 P.M.	0.02	29.99	"
5:35 P.M.	0.02	29.99	"
5:40 P.M.	0.02	29.99	"
5:45 P.M.	0.02	29.99	"
5:50 P.M.	0.02	29.99	"
5:55 P.M.	0.03	30.00	"
6:00 P.M.	0.03	30.00	"
6:05 P.M.	0.03	30.00	"
6:10 P.M.	0.05	30.00	"
6:15 P.M.	0.08	30.00	"
6:20 P.M.	0.08	30.00	"
6:25 P.M.	0.09	30.00	"
6:30 P.M.	0.10	30.00	"
6:35 P.M.	0.04	30.00	"
6:40 P.M.	0.06	30.00	"
6:45 P.M.	0.07	30.00	"

TABLE 6 (continued)

Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.	Air Flow
6:50 P.M.	0.07	30.00	575 CFM
6:55 P.M.	0.07	30.00	"
7:00 P.M.	0.07	30.00	"
7:05 P.M.	0.07	30.00	"
7:10 P.M.	0.07	30.00	"
7:15 P.M.	0.09	30.04	"
7:20 P.M.	0.07	30.04	"
7:25 P.M.	0.07	30.04	"
7:30 P.M.	0.07	30.04	"
7:35 P.M.	0.08	30.04	"
7:40 P.M.	0.08	30.04	"
7:45 P.M.	0.08	30.05	"
7:50 P.M.	0.09	30.05	"
7:55 P.M.	0.08	30.05	"
8:00 P.M.	0.08	30.05	"
8:05 P.M.	0.09	30.05	"
8:10 P.M.	0.06	30.05	"
8:15 P.M.	0.05	30.05	"
8:20 P.M.	0.05	30.05	"
8:25 P.M.	0.08	30.05	"
8:30 P.M.	0.09	30.05	"
8:35 P.M.	0.09	30.05	"
8:40 P.M.	0.08	30.05	"
8:45 P.M.	0.07	30.05	"
8:50 P.M.	0.08	30.05	"
8:55 P.M.	0.07	30.05	"
9:00 P.M.	0.03	30.05	"
9:05 P.M.	0.07	30.04	"
9:10 P.M.	0.06	30.04	"
9:15 P.M.	0.07	30.04	"
9:20 P.M.	0.10	30.04	"
9:25 P.M.	0.08	30.04	"
9:30 P.M.	0.09	30.04	"
9:35 P.M.	0.10	30.04	"
9:40 P.M.	0.12	30.04	"
9:45 P.M.	0.05	30.03	"
9:50 P.M.	0.07	30.03	"
9:55 P.M.	0.09	30.03	"
10:00 P.M.	0.06	30.02	"
10:05 P.M.	0.10	30.02	"
10:10 P.M.	0.10	30.02	"
10:15 P.M.	0.11	30.02	"
10:20 P.M.	0.11	30.02	"
10:25 P.M.	0.12	30.02	"
10:30 P.M.	0.12	30.02	"
10:35 P.M.	0.11	30.02	"
10:40 P.M.	0.11	30.02	"
10:45 P.M.	0.11	30.02	"

TABLE 6 (continued)

Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.	Air Flow
10:50 P.M.	0.11	30.02	575 CFM
10:55 P.M.	0.11	30.02	"
11:00 P.M.	0.11	30.03	"
11:05 P.M.	0.12	30.03	"
11:10 P.M.	0.12	30.03	"
11:15 P.M.	0.12	30.03	"
11:20 P.M.	0.14	30.03	"
11:25 P.M.	0.13	30.03	"
11:30 P.M.	0.20	30.03	"
11:35 P.M.	0.12	30.03	"
11:40 P.M.	0.12	30.03	"
11:45 P.M.	0.12	30.03	"
11:50 P.M.	0.12	30.03	"
11:55 P.M.	0.14	30.03	"
12:00 M	0.12	30.03	"
12:05 A.M.	0.16	30.04	"
12:10 A.M.	0.13	30.04	"
12:15 A.M.	0.13	30.04	"
12:20 A.M.	0.15	30.04	"
12:25 A.M.	0.16	30.04	"
12:30 A.M.	0.14	30.05	"
12:35 A.M.	0.15	30.05	"
12:40 A.M.	0.15	30.05	"
12:45 A.M.	0.15	30.06	"
12:50 A.M.	0.15	30.06	"
12:55 A.M.	0.15	30.06	"
1:00 A.M.	0.15	30.06	"
1:05 A.M.	0.15	30.07	"
1:10 A.M.	0.18	30.07	"
1:15 A.M.	0.15	30.07	"
1:20 A.M.	0.15	30.07	"
1:25 A.M.	0.20	30.07	"
1:30 A.M.	0.28	30.08	"
1:35 A.M.	0.20	30.08	"
1:40 A.M.	0.15	30.08	"
1:45 A.M.	0.20	30.08	"
1:50 A.M.	0.15	30.08	"
1:55 A.M.	0.15	30.08	"
2:00 A.M.	0.18	30.08	"
2:05 A.M.	0.20	30.08	"
2:10 A.M.	0.16	30.08	"
2:15 A.M.	0.20	30.08	"
2:20 A.M.	0.18	30.08	"
2:25 A.M.	0.20	30.08	"
2:30 A.M.	0.20	30.08	"
2:35 A.M.	0.18	30.09	"
2:40 A.M.	0.18	30.09	"
2:45 A.M.	0.18	30.09	"

TABLE 6 (continued)

Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.	Air Flow
2:50 A.M.	0.18	30.09	575 CFM
2:55 A.M.	0.18	30.09	"
3:00 A.M.	0.20	30.09	"
3:05 A.M.	0.20	30.09	"
3:10 A.M.	0.18	30.09	"
3:15 A.M.	0.18	30.09	"
3:20 A.M.	0.18	30.09	"
3:25 A.M.	0.18	30.09	"
3:30 A.M.	0 18	30.09	"
3:35 A.M.	0.18	30.09	"
3:40 A.M.	0.18	30.09	"
3:45 A.M.	0.26	30.09	"
3:50 A.M.	0.18	30.09	"
3:55 A.M.	0.20	30.09	"
4:00 A.M.	0.16	30.10	"
4:05 A.M.	0.20	30.10	"
4:10 A.M.	0.12	30.10	"
4:15 A.M.	0.18	30.10	"
4:20 A.M.	0.17	30.10	"
4:25 A.M.	0.17	30.10	"
4:30 A.M.	0.17	30.10	"
4:35 A.M.	0.17	30.10	"
4:40 A.M.	0.20	30.10	"
4:45 A.M.	0.18	30.10	"
4:50 A.M.	0.18	30.10	"
4:55 A.M.	0.18	30.10	"
5:00 A.M.	0.18	30.10	"
5:05 A.M.	0.18	30.11	"
5:10 A.M.	0.18	30.11	"
5:15 A.M.	0.18	30.11	"
5:20 A.M.	0.18	30.11	"
5:25 A.M.	0.18	30.11	"
5:30 A.M.	0.18	30.11	"
5:35 A.M.	0.18	30.11	"
5:40 A.M.	0.18	30.11	"
5:45 A.M.	0.16	30.11	"
5:50 A.M.	0.18	30.11	"
5:55 A.M.	0.18	30.11	"
6:00 A.M.	0.18	30.12	"
6:05 A.M.	0.18	30.12	"
6:10 A.M.	0.18	30.12	"
6:15 A.M.	0.18	30.12	"
6:20 A.M.	0.18	30.13	"
6:25 A.M.	0.22	30.13	"
6:30 A.M.	0.18	30.13	"
6:35 A.M.	0.18	30.13	"
6:40 A.M.	0.18	30.13	"
6:45 A.M.	0.20	30.13	"

TABLE 6 (continued)

Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.	Air Flow
6:50 A.M.	0.20	30.13	575 CFM
6:55 A.M.	0.20	30.13	"
7:00 A.M.	0.20	30.13	"
7:05 A.M.	0.20	30.14	"
7:10 A.M.	0.18	30.14	"
7:15 A.M.	0.18	30.14	"
7:20 A.M.	0.18	30.14	"
7:25 A.M.	0.20	30.14	"
7:30 A.M.	0.20	30.14	"
7:35 A.M.	0.24	30.14	"
7:40 A.M.	0.20	30.14	"
7:45 A.M.	0.18	30.14	"
7:50 A.M.	0.18	30.15	"
7:55 A.M.	0.18	30.15	"
8:00 A.M.	0.18	30.15	"
8:00 A.M.	0.18	30.15	"
8:05 A.M.	0.18	30.15	"
8:10 A.M.	0.18	30.15	"
8:15 A.M.	0.18	30.15	"
8:20 A.M.	0.18	30.16	"
8:25 A.M.	0.18	30.16	"
8:30 A.M.	0.18	30.16	"
8:35 A.M.	0.18	30.16	"
8:40 A.M.	0.18	30.16	"
8:45 A.M.	0.18	30.16	"
8:50 A.M.	0.18	30.16	"
8:55 A.M.	0.18	30.16	"
9:00 A.M.	0.18	30.16	"
9:05 A.M.	0.18	30.17	"
9:10 A.M.	0.18	30.17	"
9:15 A.M.	0.18	30.17	"
9:20 A.M.	0.18	30.17	"
9:25 A.M.	0.18	30.17	"
9:30 A.M.	0.18	30.17	"
9:35 A.M.	0.18	30.18	"
9:40 A.M.	0.18	30.18	"
9:45 A.M.	0.18	30.18	"
9:50 A.M.	0.17	30.18	"
9:55 A.M.	0.17	30.18	"
10:00 A.M.	0.16	30.18	"
10:05 A.M.	0.15	30.19	"
10:10 A.M.	0.15	30.19	"
10:15 A.M.	0.13	30.19	"
10:20 A.M.	0.15	30.20	"
10:25 A.M.	0.15	30.20	"
10:30 A.M.	0.14	30.20	"
10:35 A.M.	0.14	30.21	"
10:40 A.M.	0.14	30.21	"
10:45 A.M.	0.15	30.21	"

TABLE 6 (continued)

Time	Differential Mine Pressure, "H2O	Barometric Pressure, "Hg.	Air Flow
10:50 A.M.	0.13	30.20	575 CFM
10:55 A.M.	0.13	30.20	"
11:00 A.M.	0.13	30.20	"
11:05 A.M.	0.12	30.20	"
11:10 A.M.	0.13	30.20	"
11:15 A.M.	0.13	30.20	"
11:20 A.M.	0.13	30.20	"
11:25 A.M.	0.13	30.20	"
11:30 A.M.	0.13	30.20	370 CFM
11:35 A.M.	0.09	30.20	"
11:40 A.M.	0.10	30.20	"
11:45 A.M.	0.10	30.20	"
11:50 A.M.	0.10	30.20	"
11:55 A.M.	0.10	30.20	"
12:00 N	0.10	30.20	"
12:05 P.M.	0.10	30.20	"
12:10 P.M.	0.09	30.20	"
12:20 P.M.	0.10	30.20	"
12:25 P.M.	0.10	30.20	"
12:30 P.M.	0.10	30.20	"
12:35 P.M.	0.10	30.20	"
12:40 P.M.	0.09	30.20	"
12:45 P.M.	0.09	30.20	"
12:50 P.M.	0.09	30.20	"
12:55 P.M.	0.09	30.20	"
1:00 P.M.	0.09	30.20	"
1:05 P.M.	0.05	30.20	325 CFM
1:10 P.M.	0.06	30.20	"
1:15 P.M.	0.07	30.20	"
1:20 P.M.	0.07	30.20	"
1:25 P.M.	0.07	30.20	"
1:30 P.M.	0.06	30.20	"
1:35 P.M.	0.03	30.20	"
1:40 P.M.	0.05	30.20	"
1:45 P.M.	0.05	30.20	"
1:50 P.M.	0.05	30.20	"
1:55 P.M.	0.05	30.20	"
2:00 P.M.	0.05	30.20	"
2:05 P.M.	0.05	30.20	"
2:10 P.M.	0.04	30.20	"
2:15 P.M.	0.03	30.20	"
2:20 P.M.	0.03	30.20	"
2:25 P.M.	0.06	30.20	"
2:30 P.M.	0.07	30.20	"
2:35 P.M.	0.07	30.20	"
2:40 P.M.	0.07	30.20	"
2:45 P.M.	0.06	30.20	"

TABLE 6 (continued)

Time	Differential Mine Pressure, "H_2O	Barometric Pressure, "Hg.	Air Flow
2:50 P.M.	0.07	30.20	325 CFM
2:55 P.M.	0.05	30.20	"
3:00 P.M.	0.06	30.20	"
3:05 P.M.	0.06	30.20	"
3:10 P.M.	0.05	30.20	"
3:15 P.M.	0.06	30.20	"

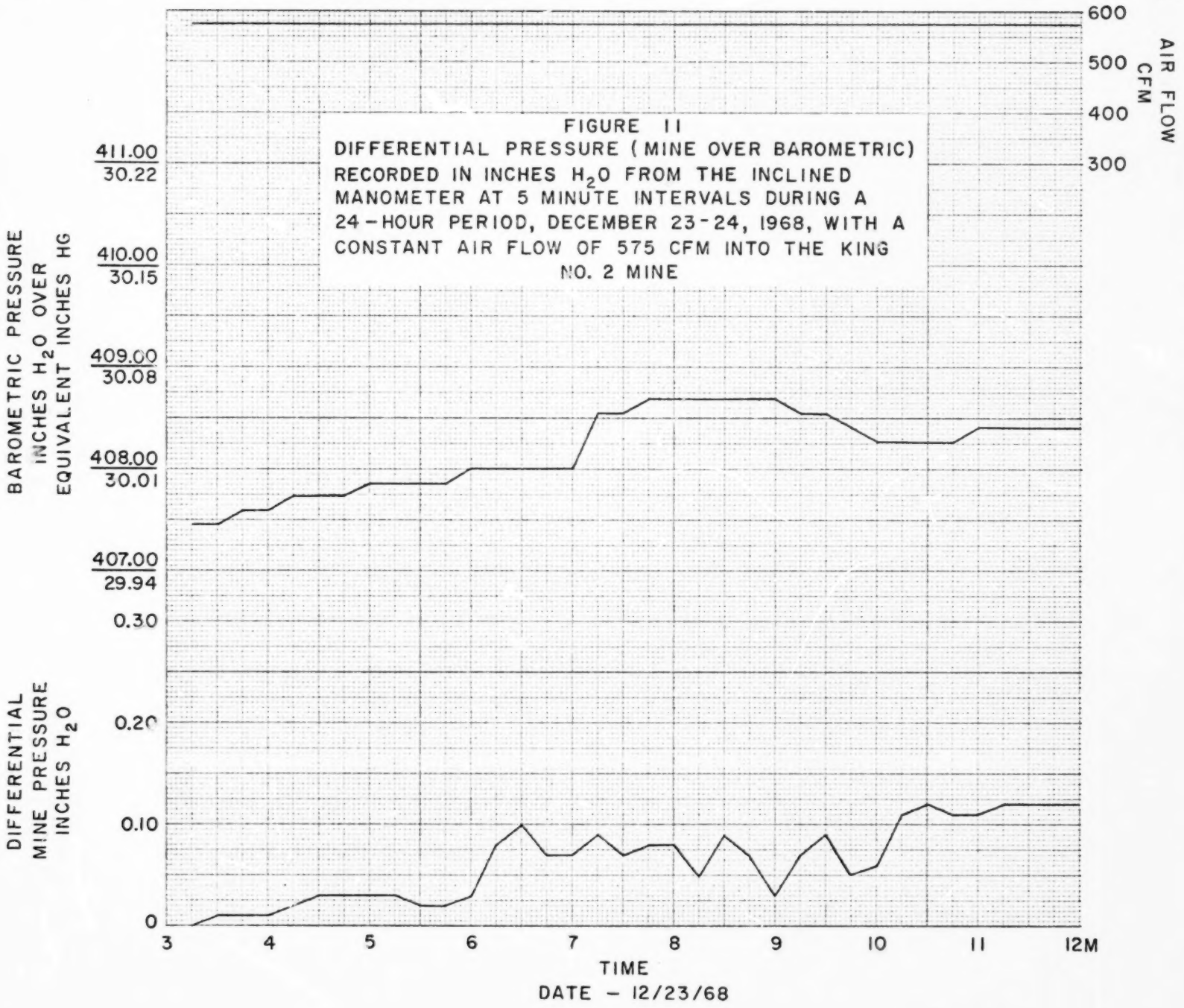


FIGURE 11
DIFFERENTIAL PRESSURE (MINE OVER BAROMETRIC) RECORDED IN INCHES H_2O FROM THE INCLINED MANOMETER AT 5 MINUTE INTERVALS DURING A 24-HOUR PERIOD, DECEMBER 23-24, 1968, WITH A CONSTANT AIR FLOW OF 575 CFM INTO THE KING NO. 2 MINE
BAROMETRIC PRESSURE INCHES H_2O OVER EQUIVALENT INCHES HG
411.00
30.22
410.00
30.15
409.00
30.08
408.00
30.01
407.00
29.94
DIFFERENTIAL MINE PRESSURE INCHES H_2O
0.30
0.20
0.10
0
AIR FLOW CFM
600
500
400
300
3
4
5
6
7
8
9
10
11
12M
TIME
DATE - 12/23/68

AIR FLOW
CFM
600
500
400
300
FIGURE III (CONTINUED)
411.00
30.22
410.00
30.15
409.00
30.08
408.00
30.01
407.00
29.94
BAROMETRIC PRESSURE
INCHES H2O OVER
EQUIVALENT INCHES HG
0.30
0.20
0.10
0
DIFFERENTIAL
MINE PRESSURE
INCHES H2O
12M
1
2
3
4
5
6
7
8
TIME
DATE - 12/24/68

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FIGURE 11(CONTINUED)